Research Article *ISSN: 2319-507X*
Pankaj Jaiswal, IJPRET, 2013; Volume 1(8): 12-22 *IJPRET*

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

A PATH FOR HORIZING YOUR INNOVATIVE WORK

STRESS AND VIBRATION ANALYSIS OF A CAM MECHANISM FOR IMPROVING MECHANICAL EFFICIENCY

PANKAJ R JAISWAL, RAHUL.B.BARJIBHE

Faculty, Department Of Mechanical Engineering, SSGB College of Engineering & Technology, Bhusawal, India

Accepted Date: 27/02/2013

Publish Date: 01/04/2013

Keywords

Follower & Cam;

Point Contact;

Vibration Analysis;

Finite Element

Corresponding Author

Mr. Pankaj R Jaiswal

Abstract

The current cam and follower mechanism in four stroke internal combustion engine employs a flat follower. In this work an attempt is made to change the flat face of follower to a curved face follower, so that the required point contact can be achieved. As line contact between existing cam and follower mechanism results in high frictional losses which results in low mechanical efficiency. It is observed that the frequency of vibration in the existing and modified cam and follower mechanism remains almost same. The finite element approach is used to perform the analysis

INTRODUCTION

In the 21th century, with the advance technologies the various vehicles have been modified as per the requirement of a consumer. Sometimes there is modified ignition system, modified shape, different cylinder arrangements etc. Thus we have decided to change the shape of a roller. The roller of the cam follower mechanism is of flat type; which makes line contact with cam. This line contact of roller with cam will be changed to point contact by doing modification in the geometry of a roller. The modified geometry of a roller should satisfy conditions: 1. It should make point contact with cam of cam-follower mechanism.2. The values of stresses of an original geometry and modified geometry should be within limit. 3. The value of frequencies of an original geometry and modified geometry should be within range. The purpose of this project to reduce the friction between roller and cam. The variety of different types of cam and follower systems that one can choose from is quite broad which depends on the shape of contacting surface of the cam and the profile of the follower. 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 to a curved face follower, so that the required point contact can be achieved to minimize frictional losses. Valves in distribution systems of internal combustion engines must ensure a suitable filling of cylinders in gasoline-air mixture for SI engines and in air for Compression ignition engines. On the other hand, for high engine speeds, valves may not have time to return to initial positions. It follows a power loss and in certain cases interference between the valve head and piston causing a broken engine [1, 2]. The dynamic behaviour of the system camshaft, follower, push-rod and valve is in a great importance in the good working of the system [3]. From design phases, engineers can predict this dynamic behaviour as function of the different parameters of the engine valve train components. Many researchers who were interested in this research field work on different aspect like variable valve timing. Through computer modeling, experimental validation, and robust optimal design strategies David [4] showed that it is possible to develop optimal design to produce optimal valve train systems. Choi [5] was interested in the elaboration of camshaft lobes profiles using implicit filtering algorithm helping parameter identification and optimization in automotive valve train design. According to Khin [10] a cam mechanism usually consists of two moving elements, the cam and the follower, mounted on a fixed frame. A cam may be defined as a machine element having a curved outline or a curved groove, which, by its oscillation or rotation motion, gives a predetermined specified motion to another element called the follower. Rocker arm generally referred to within the internal combustion engine of automotive, marine, motorcycle and reciprocating aviation engines, the rocker arm is a reciprocating lever that conveys radial movement from the cam lobe into linear movement at the poppet valve to open it. One end is raised and lowered by the rotating lobes of the camshaft (either directly or via a tappet (lifter) and pushrod) while the other end acts on the valve stem. When the camshaft lobe raises the outside of the arm, the inside presses down on the valve stem, opening the valve. When the outside of the arm is permitted to return due to the camshafts rotation, the inside rises, allowing the valve spring to close the giver. In the diagram, the drive cam (7) is driven by the camshaft (8). This pushes the rocker arm (10) up and down about the trunnion pin (20). Friction is reduced at the point of contact by a roller cam follower (21). A similar arrangement transfers the motion via another roller cam follower (22) to a second rocker arm (9). This rotates about the rocker shaft (32), and transfers the motion via a tappet to the poppet valve. In this case this opens the intake valve (6) to the cylinder head (2).

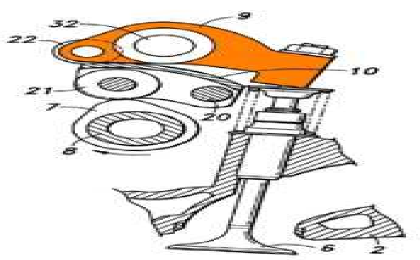


Fig 1 Rocker arm mechanism

II. PROBLEM DEFINITION AND OBJECTIVE

The existing cam & follower mechanisms used in Internal Combustion engines have a line contact between them causing 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.

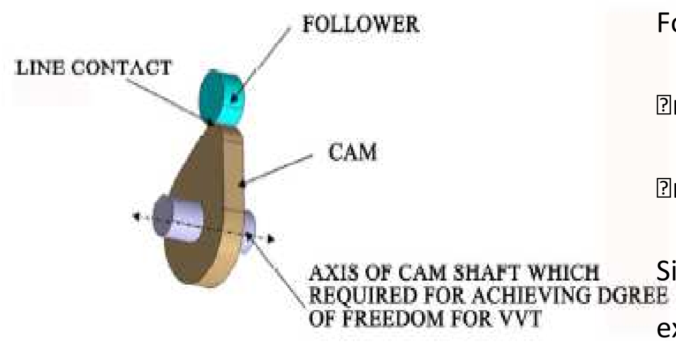


Fig.2.Existing cam & follower mechanism.

III DESIGN CALCULATIONS

3.1 Analysis for Roller:

C/S Area of Hatching Portion in Existing Roller (A) =112.05 mm2

C/S Area of Hatching Portion in Modified Roller (A) = 106.60 mm2

Maximum load from the cam is (P) 675N (68.80Kg)

So we have to find out static stress in existing & modified roller (As shown in figure 5.1)

For Existing Roller

σex roller =P/A=675/112.05

σex roller=6.02 N/mm2

For Modified Roller

σmod roller =P/A=675/106.60

σmod roller=6.33 N/mm2

Similarly we have to find out deformation in existing & modified follower roller

3.2 Linear & Lateral Strain:

$$\text{Strain, } \varepsilon = \delta l / l$$

3.3 Young's Modulus or Modulus of Elasticity:

Material: 100Cr6

Young's modulus 2.1e5MPa

ISSN: 2319-507X
IJPRET

Poisson's Ratio: 0.3

Linear Strain for existing roller

E=?/ε

2.1e5=6.02/ ε

εex rollar = 2.86 e-5 mm

Linear Strain for modified roller

E=?/ε

2.1e5=6.33/ ε

εmod rollar = 3.01 e-5 mm

3.4 Deformation of roller material in both cases

Linear strain=εex roller = 2.189 e-4 mm

$$\frac{\text{change in length}}{\text{original length}} = \text{linear strain}$$

$$\frac{\delta l}{L} = \varepsilon$$

$$\frac{\delta l}{6.43} = 2.06\ e - 5$$

δl ex roller =1.83 e-4 mm

$$\frac{\delta l}{6.43} = 3.01\ e - 5$$

δl mod roller =1.93 e-4 mm

Lateral Strain Existing Roller

$$\frac{\text{Lateral strain}}{\varepsilon} = \mu$$

$$\frac{\text{Lateral strain}}{2.86\ e - 5} = 0.3$$

Lateral strain=8.58 e-6 mm

$$\frac{\delta d}{d} = \text{Lateral strain}$$

$$\frac{\delta d}{17.46} = 8.58\ e - 6$$

δd ex Roller =1.49 e-4 mm

Lateral Strain modified Roller

$$\frac{\text{Lateral strain}}{\varepsilon} = \mu$$

$$\frac{\text{Lateral strain}}{3.01\ e - 5} = 0.3$$

Lateral strain=9.03 e-6 mm

$$\frac{\delta d}{d} = \text{Lateral strain}$$

$$\frac{\delta d}{17.46} = 9.03\ e - 6$$

δd mod. Roller =1.576 e-4 mm

IV. FINITE ELEMENT ANALYSIS PROCEDURE

Roller follower first modeled in CATIA V5 which is excellent CAD software, which makes modeling so easy and user friendly. The model is then transferred in IGES format and exported into the Analysis software ANSYS 12.0.

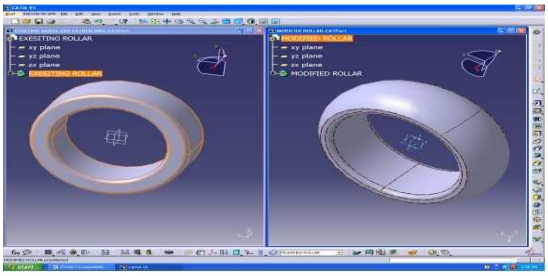


Fig.3 Solid model of existing & modified roller.

4.1 Boundary Conditions

3D modeling of a roller is done in CATIA and it is called in ANSYS through an 'IMPORT-IGES' option. Roller is having a fillet of 0.5mm. Inner surface of a roller is constrained as it is locked due to needle bearing and lock nut. Load shown is uniformly distributed on a plane (flat) surface of a roller on upper side as cam is in line contact with roller on its upper part. Load is applied in vertically downward direction and is a magnitude of 675N (68.80Kg). Load value is taken from graph shown

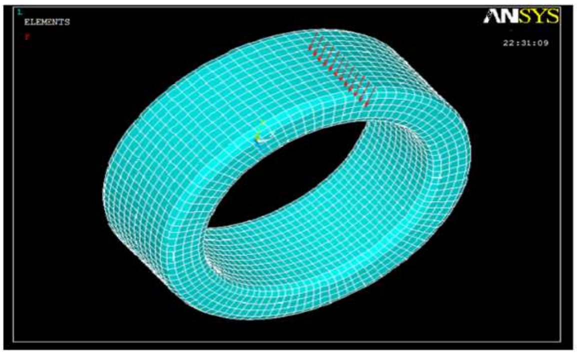


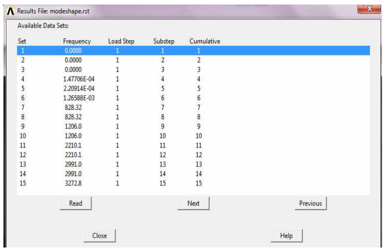
Fig. 4 Meshed model of follower.

4.2 Natural Frequency of Existing Follower with Line Contact

The Figure 5 shows the frequency range for 15 sets of the existing follower with line contact which is fixed and this same frequency range used in the modified roller follower. Figure 6 shows the modal analysis at the 828.32 HZ frequency and element behavior. Red colour zone indicates the deformation of existing roller follower having range from 16.015 mm [min.] to 17.436 mm [max.]. Blue colour zone indicates the deformation of existing roller follower having range from 4.642 mm [min.] to 6.064 mm [max.]. Figure 7 shows the modal analysis at the 1206 HZ frequency & element behavior. Red colour zone indicates the deformation of existing roller follower having range from 22.439 mm [min.] to 25.173 mm [max.]. Blue colour zone indicates the deformation of

ISSN: 2319-507X
IJPRET

existing roller follower having range from 0.569 mm [min.] to 3.304 mm [max.]. Figure 8 shows the modal analysis at the 3272.8 HZ frequency & element behavior. Red colour zone indicates the deformation of existing roller follower having range from 21.649 mm [min.] to 23.41 mm [max.]. Blue colour zone indicates the deformation of existing roller follower having range from 7.558 mm [min.] to 9.319 mm [max.]. All these frequency range were used in existing follower and same frequency range and steps were followed in modified follower.


Results File: modeshape.rst

Available Data Sets:

Set	Frequency	Load Step	Substep	Cumulative
1	0.0000	1	1	1
2	0.0000	1	2	2
3	0.0000	1	3	3
4	1.47706E-04	1	4	4
5	2.20914E-04	1	5	5
6	1.26588E-03	1	6	6
7	828.32	1	7	7
8	828.32	1	8	8
9	1206.0	1	9	9
10	1206.0	1	10	10
11	2210.1	1	11	11
12	2210.1	1	12	12
13	2991.0	1	13	13
14	2991.0	1	14	14
15	3272.8	1	15	15

Read Next Previous
Close Help

Fig.5 First 15 modes of vibration.

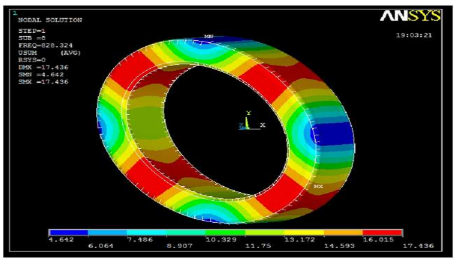


Fig.6 Nodal displacement Solution 7thfrequency (828.32 HZ).

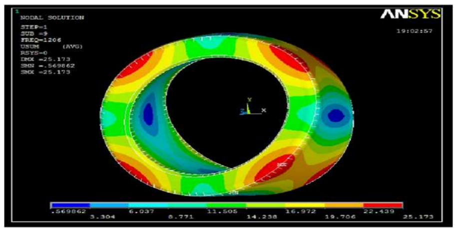


Fig.7 Nodal displacement Solution 10th frequency (1206 HZ).

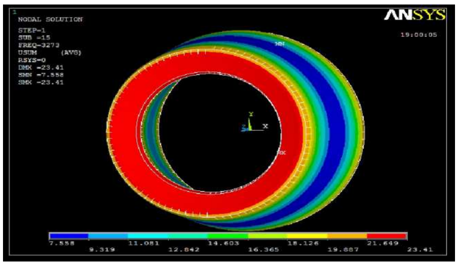


Fig.8. Nodal displacement Solution 15th frequency (3272.8HZ).

4.3 Natural Frequency of a curved face Roller Follower

Figure shows the frequency range for 15 sets which were used in the existing follower with line contact are used in the modified roller follower. Figure 9 shows the Modal Analysis and element behavior of modified follower under frequency of 953.60 HZ. Red colour zone indicates the deformation of modified roller follower having range from 13.898 mm [min.] to 15.256 mm [max.]. Blue colour zone indicates the deformation of modified roller follower having range from3.034 mm [min.] to 4.392 mm [max.]. Figure 10 shows the Modal Analysis and element behavior of modified follower under frequency of 1284.2 HZ. Red colour zone indicates the deformation of modified roller follower having range from 18.201 mm [min.] to 20.416 mm [max.]. Blue colour zone indicates the deformation of modified roller follower having range from 0.477 mm [min.] to 2.692 mm [max.]. Figure 11 shows the modal analysis and element behavior of modified follower under frequency of 3162.7 HZ. Red colour zone indicates the deformation of modified roller follower having range from 19.278 mm [min.] to 21.675 mm [max.]. Blue colour zone indicates the deformation of modified roller follower having range from 0.0975 mm [min.] to 2.495 mm [max.].

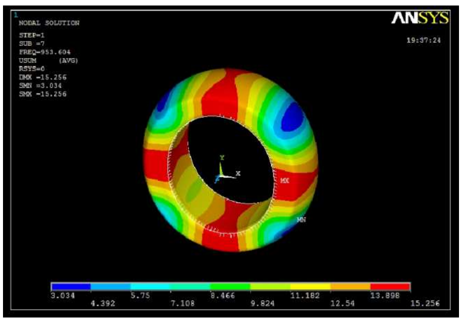


Fig.9. Nodal displacement Solution 7th frequency (953.60 HZ).

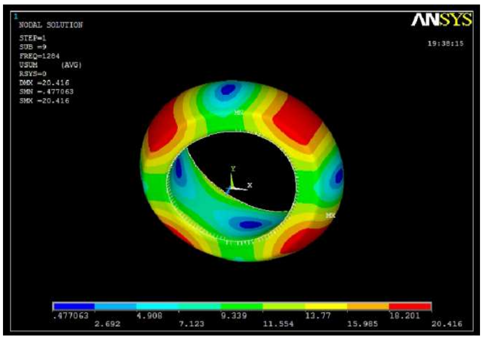


Fig.10. Nodal displacement Solution 10th frequency (1284.2HZ).

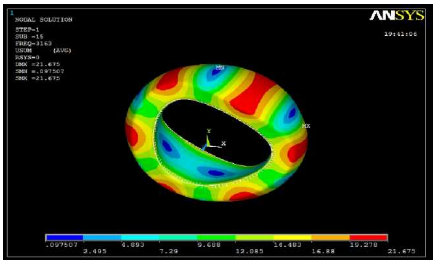


Fig.11. Nodal displacement Solution 15th frequency(3162.7HZ).

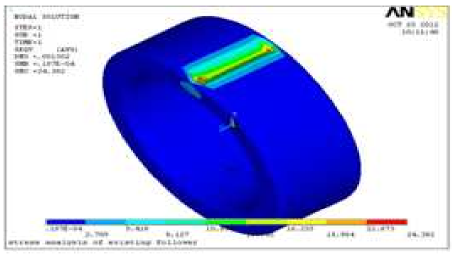


Fig.12 Stress analysis flat roller follower.

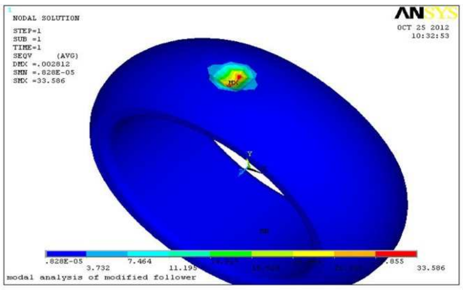


Fig.13 Stress analysis modified roller follower.

V RESULTS AND DISCUSSION

Modal & stress analysis of existing and modified follower is carried out. As per the conditions initially frequency range was fixed and then the Modal analysis is performed. Frequency range of modified roller follower shows a very good match with the frequency range of existing roller follower. The obtained frequency range of existing roller follower is 828.32 HZ (Fig.6) to 3272.8 HZ (Fig.8) and for modified roller is 953.60 HZ (Fig.9) to 3162.7 HZ (Fig.11).As frequency range of modified roller follower is within the frequency range of existing roller follower. Thus, the modified design proves to be safe. From modal analysis it is observed that the maximum values of deformation for modified roller follower is 21.675 mm, while for existing roller follower is 23.41 mm for the obtained frequency& in case of static stress analysis value of deformation in both cases is very small or it negligible. This shows modified roller follower deforms comparatively less as compared existing roller follower in case model analysis. This indicates change of the flat face of roller follower to a curved face roller follower mechanism results in low frictional losses due to point contact which results in improved in mechanical efficiency of internal combustion engine.

Result Analysis between Existing & Modified roller			
Sr.No	Type of analysis	Existing Roller	Modified Roller
Theoretical stress analysis			
1	Stress Analysis	6.02 N/mm^2	6.33 N/mm^2
Material Deformation			
1	Lateral Direction	1.49xe-^{4} mm	1.576xe-^{4} mm
2	Linear Direction	1.83xe-^{4} mm	1.93xe-^{3} mm
FEA Analysis using ANSYS			
1	Static Stress	5.418 N/mm^2	6.464 N/mm^2
Material Deformation			
2		2.90 xe-^{4} mm	3.12xe-^{4} mm
Free Vibration Analysis of Roller			
1	Natural Frequency	828.32 HZ	953.60HZ
2		1206.9 HZ	1284.2 HZ
3		2210.1 HZ	2478.7 HZ
4		2991.0 HZ	3026.4 HZ
5		3272.8 HZ	3162.7 HZ
1	Deformation Of Roller	17.43	15.256
2		25.17	20.416
3		23.41	21.675

VI CONCLUSION

In this work finite element approach is used to optimize the shape of flat face of existing follower into a curved face of modified follower, so that the required point contact can be achieved. Frequency range of modified roller follower shows a very good match with the frequency range of existing roller follower. As frequency range of modified roller follower is within the frequency range of existing roller follower, the modified design proves to be safe. This indicates change of the flat face of roller follower to a curved face roller follower mechanism results in low frictional losses due point contact which results in improved in mechanical efficiency of internal combustion engine.

Acknowledgment

I would like to thank Prof. Rahul.B.Barjibhe for his contribution.

REFERENCES

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

2. H. D. Desai and V. K. Patel, "Computer Aided Kinematic and Dynamic Analysis of Cam and Follower," Proceed-ings of the World Congress on Engineering, Vol. 2, 30 June-2 July 2010, London, pp.117-127

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

4. Yuan L. Lai, Jui P. Hung, and Jian H. Chen," Roller Guide Design and Manufacturing for Spatial Cylindrical Cams", World Academy of Science, Engineering and Technology,vol. 38, 2008,pp.109-118.

5. A. Rivola, M. Troncossi, G. Dalpiaz and A. Carlini, "Elastodynamic analysis of the desmodromic valve train of a racing motorbike engine by means of a combined lumped/finite element model",DIEM—Department of Mechanical Engineering, University of Bologna, 21,2007, pp.735–760.

6. H. Heisler, "Advanced Engine Technology," Butterworth-Heinmann, Oxford, 2002, 2nd Edition, pp 101-108.

7. M. Husselman, "Modeling and Verification of Valve Train Dynamics in

Engines," M.Sc. Thesis, Stellenbosch University, Stellenbosch, 2005, pp212-223.

8. R. L. Norton and R. G. Mosier, "Cam Design and Manufacturing Handbook," Industrial Press, Inc., New York, 2002.pp 98-112.

9. J. W. David, C. Y. Cheng, T. D. Choi, C.T. Kelley and J. Gablonsky, "Optimal Design of High Speed Mechanical Systems," North Carolina State University, Raleigh, Tech.Rep. CRSC-TR97-18, 1997,pp 84-97.

10. Tounsi M., Chaari F., Walha L., Fakhfakh T., Haddar M, "Dynamic Behavior Of A Valve Train System In Presence Of Camshaft Errors," Wseas Transactions On Applied And Theoretical Mechanics, Vol.No. 6, 2011, pp. 17-26.

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

12. Faculty Of Mechanical Engineering,"Design Data Book Of Engineers", Kalaikathir Achchagam, 2011 , 7.110-7.116.