

Comparative Analysis of Four Cylinder Engine Camshaft Material

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Abstract: One of the main concerns of engineers in the field of internal combustion engines is to extend the service life of the components. Also, automotive manufacturer continually increase power train parameters, e.g. the output power and torque together with weight reduction, but this often leads to higher noise and vibration. The aim of this paper is to suggesting a better material for camshaft by comprising 2 different materials such as Grey C.I. and SAE 52100 on the basis of natural frequency, stress and deflection, wear and friction, bending strength, so it minimize vibration problem and increase service life of camshaft. From the frequency, stress and deflection obtained it is observed that the material SAE52100 gives highest natural frequency, less stress and deflection, high bending strengths than currently used material (Grey C.I.). But it is observed that specific wear rate and coefficient of friction of SAE 52100 and Grey C.I. same in all conditions, which is does not adversely affect on fuel economy. So the SAE 52100 material is most suitable material for camshaft amongst the selected materials for analysis.

Keywords: Camshaft, Vibration, Wear, Friction, Bending Strengths

I. INTRODUCTION

The valve train is one of the most complex and critical parts of the automotive engine. The valve lifts characteristics are not only radically contribute to engine efficiency and performance but also severely influence the engine emissions levels. Adversely, the valve train is a major contributor to engine vibrations and noise levels. A wide number of different design solutions are being developed for this mechanism to study crucial function of the valve train. The camshaft is one of part of valve train assembly, thus it is necessary to perform analysis of this part. A camshaft has a function to carry through the movement which results in the opening and closing of intake and exhaust valves with specified times of engine functioning [11]. It consists of cam lobes which are driven by gears, a belt, or chain from the crankshaft.

The widespread use of finite element models in assessing system dynamics for noise, vibration, and harshness (NVH) evaluation is used to improve the procedures for comparative analysis of models and experimental results [10]. The empirical and iterative torsional vibration analysis is reported so far in the literature, this analysis is performed for a one degree of freedom only. Though more degrees of freedom can consider the other modes of vibration and stress distribution [4]. Since last decade advent of powerful finite element analysis (FEA) packages have proven good tool. The complicated geometry of camshaft and the complex torque application makes it's analysis difficult. The various customize FEM packages have help the designer for critical stress investigation of torsional vibration [6]. These packages provides the optimize meshing and accurate simulation for complex torque application. FEM enables to find critical locations and quantitative analysis of the stress distribution and deformed shapes under loads. However detailed modeling and specialized knowledge of FEM theory are indispensable to perform these analyses with high accuracy. It also required the complicated meshing strategies. Simulations of actual boundary conditions to equivalent FE boundary conditions are to perform carefully to avoid the deviations in results. The solution of such large scale FEM problem requires large memory and disc space as computing resources.

In the investigation of reduction in NVH, many researchers [1-11] have investigated different engine component for different material and different manufacturing processes. The M. L. Pang, S. P. Smith, R. Herman and B. Buuck in 2006 have reported the FEM analysis of exhaust valve train for different loads. The follower in valve train as a component is observed in there research for analysis [4].

The investigation of camshaft by FEA may results in nevality in analysis of valvetrain. Thus the camshaft of 4-cylinder, 4-stroke diesel engine is consider for analysis in this paper.

II. METHODOLOGY

To find out the materials natural frequency, stresses and deflection, wear rate and friction, bending strenghts following methodology is consider.

1. For finding out natural frequency of camshaft first 3D model of camshaft is create in pro-e wild-fire software then mesh in Hypermesh software. By applying boundary condition, natural frequencies are finding out in Ansys. For validation of this methodology frequency obtain from ansys compare with the frequency obtain form FFT analyzer.
2. The materials friction and wear rate is finding using pin on disk test rig.
3. The bending strength by using bending test rig.

III. SOLID MODELING AND FE MESH GENERATION OF CAMSHAFT

The solid model is essential to carry out FEM analysis of any component. It is also called body in white. This can be done in special CAD package like Pro-E Wildfire. For generation of a 3-D model, 2-D orthographic views are required as shown in fig.1.

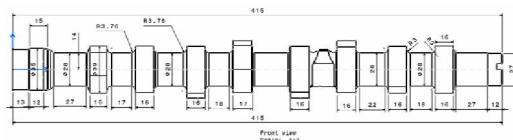


Fig.1: 2D Drawing of camshaft

Using 2-D drawings it can be possible to prepare isometric views of a component to develop the solid. The complete 3-D model is registered in fig.2.

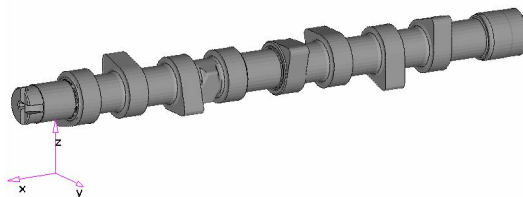


Fig. 2: A 3-D plot of the camshaft used for a specific engine

In order to perform a finite element analysis, the developed model must be divided into a number of small pieces known as finite elements. The meshing is done using Hypermesh software. The fine mesh model obtained from the mesh generation technique is shown in fig.3.



Fig. 3: A 3-D plot with meshing of the camshaft used for a specific engine

IV. ANSYS RESULTS

By applying boundary condition to mesh model in ansys software the 8 natural frequencies got is shown in table 1.

Table 1: Natural frequency of 2 materials

Mode	Grey C.I.	SAE52100
1	663.22	916
2	663.87	917
3	1769.7	2443
4	1775.6	2452
5	2391.9	3272

6	3301.2	4556
7	3304.2	4560
8	4516.3	6239

V. RESULTS OF CONTACT ANALYSIS

Displacement obtained at the nodes from the basis for estimation of stresses in the model. Using the element shape function and the strain displacement matrix, strain vector is evaluated. This strain vector is used to estimate normal stresses in each element in global co-ordinate system. From these stress components, principal stress are calculates. For a material, vonmises or equivalent stress, σ is known to give values closer to experimental ones. These vonmises stress are then calculated using the principal stress. The above procedure gives stress for a particular excitation frequency. This procedure is repeated for all frequencies in operating speed range of the engine. Stress at the critical regions of interest is recorded for the entire frequency range. This gives a stress frequency spectrum at selected point of camshaft. Boundary condition applies to camshaft while doing contact stress analysis is shown in fig. 4.

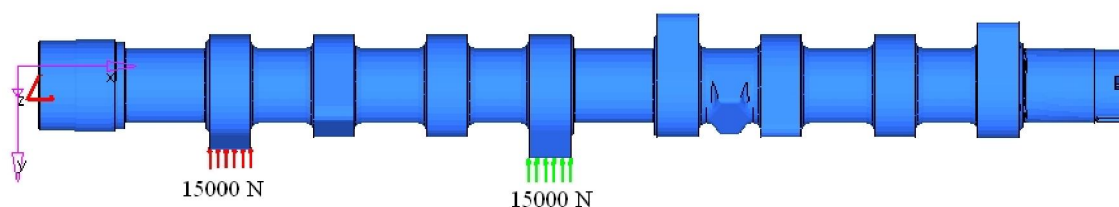


Fig. 4: Load Case (a) Bending Load= 15000N on Lobe 1 and 4

Table 2 shows these stresses and deflection for the selected camshafts.

Table 2: Max. Stress Values in N/mm^2 and Deflection in mm for 2 Materials

Material		Grey C.I.	SAE52100
Deflection (mm)	Ux	0.23	0.12
	Uy	0.0016	9.00E-04
	Uz	0.0013	7.70E-04
	Usum	0.99	0.509
Stress (N/mm^2)	Sx	514	510
	Sx	133	130
	Sx	156	140
	Vonmises Stress	524	510

VI. WEAR ANALYSIS

Cam/ tappet wear is not a major issue in a well designed valve train. However, one of the aims for a new engine is to reduce the cost of ownership. It is therefore a target to extend the intervals for lash adjustment as far as possible. From this aspect a factor of wear is consider in this project for comparative study between present and optimize material. A pin-on-disk wear-testing machine was employed to evaluate wear resistance of presently use Grey C.I. and 52100 material samples. Wear tests were conducted at room temperature, a humidity of 25–35%.



Fig.5 Pin on Disc Tribometer (TR20 LE)

Table 3: Specific wear rate and C.O.F in dry condition

Sr. No.	Speed (rpm)	Load (N)	Grey C.I		SAE52100	
			COF μ	Sp. Wear rate mm^3/Nm	COF μ	Sp. Wear rate mm^3/Nm
1	500	P ₁ =20.6	0.18883	1.51902E-06	0.69272	7.74473E-06
		P ₂ =35.316	0.03596	2.14129E-06	0.53347	4.00304E-06
		P ₃ =50.031	0.33959	1.5115E-06	0.47910	2.5688E-06
2	1000	P ₁ =20.6	0.32282	2.23407E-06	0.73155	9.68095E-06
		P ₂ =35.316	0.11270	2.50154E-06	0.62436	3.75231E-06
		P ₃ =50.031	0.54626	2.39643E-06	0.68418	1.02164E-05
3	1500	P ₁ =20.6	0.31456	2.39039E-06	0.49757	7.51265E-06
		P ₂ =35.316	0.55216	7.09683E-06	0.51818	2.71431E-05
		P ₃ =50.031	0.59583	1.26544E-05	0.45392	3.9086E-05

Table 4: Specific wear rate and C.O.F in wet condition

Sr. No.	Speed (rpm)	Load (N)	Grey C.I		SAE52100	
			COF μ	Sp. Wear rate mm^3/Nm	COF μ	Sp. Wear rate mm^3/Nm
1	500	P ₁ =20.6	0.00000	1.56818E-06	0.00340	7.68487E-07
		P ₂ =35.316	0.00000	4.57364E-07	0.00085	4.48262E-07
		P ₃ =50.031	0.00000	1.93707E-06	0.00120	3.1642E-07
2	1000	P ₁ =20.6	0.00000	3.9686E-07	0.00000	3.9686E-07
		P ₂ =35.316	0.00000	2.3149E-07	0.01246	2.54639E-06
		P ₃ =50.031	0.00000	9.8043E-07	0.00060	1.63405E-06
3	1500	P ₁ =20.6	0.00000	1.3612E-06	0.00922	2.05289E-06
		P ₂ =35.316	0.00340	4.76395E-07	0.00340	1.19746E-06
		P ₃ =50.031	0.00200	6.72558E-07	0.00600	1.05658E-06

VII. BENDING TEST

Surface cracks can be initiated by the near-surface plastic deformation caused by the contact stress of the follower, by defects such as dents or scratches, or by thermal stresses generated during the manufacturing grinding process. Once they are originated, surface cracks usually propagate at an angle to the surface. After reaching a critical depth or length, these cracks either branch up toward the free surface, so that a piece of material is removed thus leaving behind a pit, or branch down at a steep angle causing catastrophic failure. As the load on cam is in vertical direction the bending strength of cam must be high to prevent crack propagations in order to prevent failure. Results of bending test carried out on sample material as shown in table 5

Table 5: Bending test result

Sr. No.	Material Sample	Load	Conclusion
1	Grey C.I.(40 HRC)	7848 N	break
2	52100 (40 HRC)	9319.5 N	Show cracks

VIII. RESULT AND DISCUSSION

From table 1 and 2 it is observed that first mode natural frequency of Grey C.I. and SAE 52100 are 663.22, and 916.28 respectively, so material 52100 have highest natural frequency then Grey C.I. in all mode. The maximum stress developed in Grey C.I. and 52100 taken for analysis is 524 and 510 N/mm² respectively. In 52100 material 2.7% less stress observed than currently used material (Grey C.I.). The maximum deflection in Grey C.I. and 52100 taken for analysis is 0.99 and 0.509 mm respectively. In 52100 material 94% less deflection observed than currently used material (Grey C.I.). From above results it is observed that the material 52100 have high natural frequency, low stress and deflection.

Although we compare 2 different materials on the basis of frequency, stress and deflection, it is necessary to consider other aspects of materials such as friction, strength, fatigue, creep, bending etc. So comparative study between 52100 materials and Grey C.I. by considering two aspects such as friction and bending strength are done. From table 3, 4 and 5 it is observed that Sp. wear rate of Grey C.I. is less than the 52100 in all conditions. C.O.F for Grey C.I. and 52100 materials are in between 0.03-0.73 in dry condition and in between 0.0-0.012 in wet condition. Grey C.I. breaks at 7848 N load where as 52100 show cracks at 9319.5 N.

IX. CONCLUSION

From results obtained during the analysis of 2 different materials, it can be concluded that material 52100 has high natural frequency, low stress and deflection. Material 52100 shows high sp. wear rate as compare to Grey C.I. is due to low silicon, nickel content and unfavorable distribution of Si particles. So, by increasing Si, Ni content in 52100 material we might increase the wear resistance of 52100. C.O.F. of 52100 and the Grey C.I. material is in between 0-0.8 in all conditions, which is does not adversely affect on fuel economy. The bending strength of 52100 is greater than the Grey C.I. Due to this fact cracks present in lobe might not propagate and lead to increase in service life of camshaft. So the 52100 material is good for camshaft then Grey C.I.

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