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An Analysis of Camshaft Vibration Using FEM

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Abstract: *The camshaft is a critical component in internal combustion engines, responsible for controlling valve timing and engine performance. However, vibrations in the camshaft due to dynamic loads and high-speed rotation can lead to mechanical failure, reduced efficiency, and noise generation. This study presents a Finite Element Method (FEM)-based analysis to investigate the vibrational characteristics of a camshaft, helping to optimize its design for enhanced durability and performance.*

The research involves modeling the camshaft using CAD software and performing modal and harmonic analysis using FEM tools. Key parameters such as natural frequencies, mode shapes, stress distribution, and deformation under dynamic loading conditions are examined. The influence of material properties, cam profile design, and boundary conditions on vibration behavior is also analyzed.

The results provide insights into resonance conditions, critical frequencies, and structural weaknesses, offering recommendations for design modifications, material selection, and damping techniques to minimize vibrations. This study contributes to the improvement of camshaft reliability and efficiency, supporting the development of high-performance and low-noise engine systems.

Key Words: Camshaft, total deformation, valve-trains, vibration analysis, natural frequency, combustion chamber, exhaust pressure, gas pressure

I. Introduction

To control the engines exhaust and the inlet timings in the engine camshafts are used. The not only controls the timing of the valve openings and closing but also bears the load of the exhaust valve pressure and the inlet time by time. Therefore camshaft is also called the brain of the engine, hence if the brain would have any problem in operation then there will be a negative effect on the engine body. Therefore it is very essential to take care of the particular engine part. The main problem is the vibration in the camshaft and the deformation occurred when it is operated without any servicing precautions. This degrades the engine performance and it also costs the engine part material with money and time. To make work of camshaft in precise way, it is require in order to design a good mechanism linkage of camshaft. To design good mechanism linkages the dynamic behaviour of the components must be considered, this includes the mathematical behaviour of physical model. In this case, introduction of two mass, single degree of freedom and multiple degree of freedom dynamic models of cam follower systems are studied. In four strokes engine one of the most important component is camshaft, such an important part and that over the year's subject of extensive research. In this study, causes of fracture of camshaft are discuses. By using scanning electron microscopy and finite element analysis methods are used for fracture analysis of camshaft. The camshaft rotates ½ times the crankshaft or once per four-cycle stroke. The camshaft may operate the: Valve train, Mechanical fuel pump, Oil pump, Distributor, Major function is to operate the valve train. The lobes on the cam open the valves against the pressure of the valve springs.

Bearing journal can be internally or externally lubricated (oiled). Camshafts should made of the material that has the high torsional strength and at the same time it should have less weight. The deformation in the camshaft may cause the natural damage to the various parts of the engine head like the rocker arms valve-trains assembly and finally also degrade the engine performance. It also causes the friction between the valve-train parts that requires more power to operate. The frequency of the camshaft and the deformation due to loads are carried out with the help of the finite element method. Finite element method provides the approximate values of the problem but they also provide the maximum safe values for the design and operation. The analytical and the theoretical values are compared. This study has presented the vibration diagnosis and the total deformation in the camshafts of the different materials.FE analysis consists of various but mainly three steps. One the preprocessor in which we define the problem and the exact meaning of the problem. Creating the mesh and applying the boundary conditions (loads and constraints). Second is the solution in this step the solution is done by the solver engine, it helps to create the mathematical model for the problem and the given geometry then it gives the solution to the problem. Third is the post processer who implements the results on the geometry and calculate the exact effect on the final geometry. It creates the results file which can be easily read and understand by anyone. All these process are done by the software called ANSYS, the software which is used to calculate the total deformation in the given geometry.

II. Modelling Of Camshaft

The model of the full three cylinder spark ignition engine camshaft is being designed with the exact dimensions and constraints in Dassault systems Solidworks. And then is imported to the ANSYS for the Modal analysis i.e. vibration analysis. The model file can be import using the neutral file formats available IGES, STEP, ACIS, Para solid, DXF, etc.

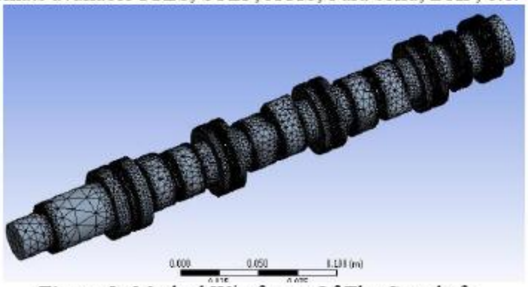

Figure 1: Meshed Wireframe Of The Camshaft

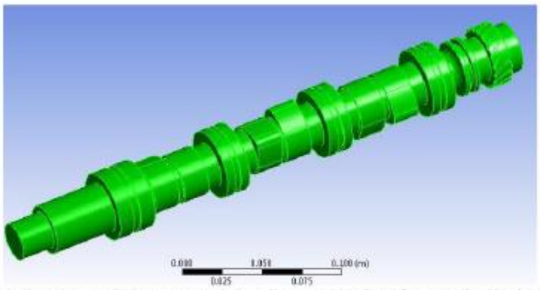

Figure 2: Solid 3-D Model Of Cam Shaft Of A 3-Cyalinder Engine

3. Problem Description

$= 0.080 \times 9.8/1.065$

$= 7.36$ N/m

Natural Frequency (both ends fixed):

$F_n = [\pi/2(n+1/2)\sqrt{(gEI)}]/WL^4$

For n=1

$F_n = 10.152$ Hz

For n=2

$F_n = 28.2$ Hz

For n=3

$F_n = 55.27$ Hz

Table 3: Experiential Data

Mode	Frequency [Hz]
1.	11.594
2.	11.596
3.	31.948
4.	31.953
5.	62.642
6.	62.647

4. Analytical Solution

The analysis shows the same solutions for the problem as they were in the theoretical problem. Now the same conditions are applied to the camshaft that is having the both ends fixed and supported and various materials have been tested.

4.1 Material Properties

Materials used	Young's Modulus (Pa)	Poisson's Ratio	Bulk Modulus(Pa)	Shear Modulus (Pa)
Cast iron	1.1e+011	0.28	8.3333e+010	4.2969e+010
Billet steel	2.e+011	0.3	1.6667e+011	7.6923e+010
EN24 steel	2.6e+011	0.27	1.8841e+011	1.0236e+011
EN8D steel	2.1e+011	0.3	1.75e+011	8.0769e+010

To study the vibration and the natural frequency in the model is the main problem of the study. One can only determine the deformation by calculating the force generated by the cylinder but no one can determine the exact same conditions of the loading and exact environment in which the camshaft is operating. There is no direct method to calculate the exact loading and boundary conditions. Therefore there will be a slight deflection between the both values. For the solution here we have used the ANSYS software for analytical solution of the problem and the theoretical solution is being done by own studies. Analysis of the natural frequency of a shaft (no load condition):

Table 1: Shaft Specifications

Elasticity of shaft	189×10^9 N/m
Length of shaft	106.5 Cm
Diameter	.3 Cm
Mass	80 gm
Gravity	9.8 m/sec^2

Table 2: Boundary Conditions

Speed when both ends are fixed	Speed when simply supported	Speed when one end is freed
760 rpm	415rpm	610rpm

$I = \pi/64 \times d^4$
$= \pi/64\ (3\times10^{-3})^4$
$= 3.96\times10^{-12} m^4$
W= weight per unit length

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EN8D steel	2.1e+011	0.3	1.75e+011	8.0769e+010

4.2 Analysis Procedure

First step is to prepare the 3D cad model in any of the 3D cad software here we have used the solidworks for this purpose. Solid modelling is done with exact dimension of a 3 cylinder SI engine camshaft. Then the solid model is being imported to the ANSYS software using the given neutral file formats. Then it is opened in the workbench to analyse the analysis procedure takes 4 steps. But first we have analysed the masses and the deformation in the camshafts with different materials.

Figure 3: Variation Of Weight Of Camshaft Of Different Materials

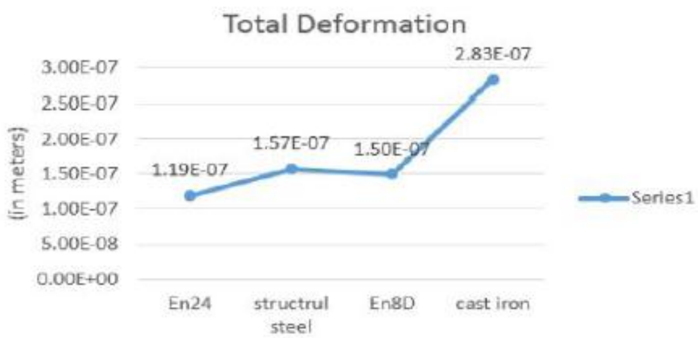

Figure 4: Variation In Total Deformation Of Different Materials

After analyzing the various material we can see the material which is having the lowest mass having the highest value of deformation and the material that have the lowest deformation have the highest mass. So if the material is to be choosing from the given data it is EN8D which is having the lower weight value and the lower deformation in the operating conditions. For the vibration analysis the MODAL ANALYSIS in ANSYS Workbench. This process includes the following four steps.

4.2.1 Pre procedure

This step specifies the 2D CAD geometry of the model in the ANSYS workbench environment and all the dimensioning of the model is converted according to the module. Most preferably we should take the same dimensions in the analysis as they were taken in the cad modelling geometry. Else the values of the results will be much distorted and off the limits sometimes.

4.2.2 Meshing

Meshing is the process of dividing the model in the small and discreet elements called the meshing elements, there are various type of meshing elements present in the software like brick elements, pyramidal, spherical, cubical triangular etc. meshing is done because it is so easy to calculate the problem for a small element than a bulk material therefore it is said that finer the mesh better will be the results. For the current project we have employed the mashing according to the curves and proximity.

4.2.3 Applying loads

This step is so important for the analysis because it defines the boundary for the results of the problem. And the scope of results is defined in this step. All the loads on the models and the boundary conditions should be applied at the exact locations for the exact solutions to the problem.

4.2.4 Post process

This step specifies the results to the problem, first the postprocessor reads the problem and the boundary conditions then it generates the mathematical model of the problem then the equation to the solutions are formed and the results are calculated. Then the results are applied to the geometry to show the final shape of the geometry if it is feasible then it would generate the final results but if it is not possible then it returns back to the pre-processor to generate the mathematical model again and run the solution again until the desired solution is obtained.

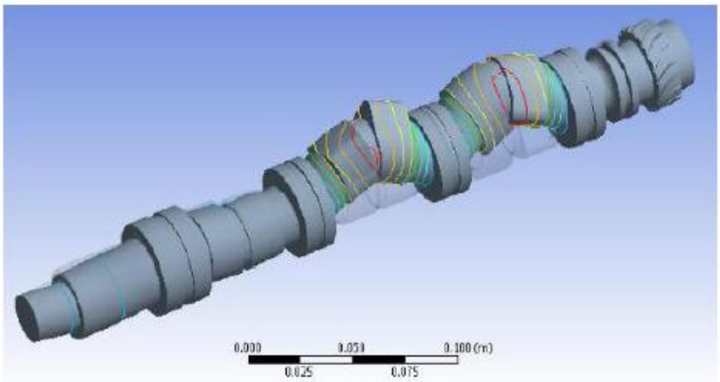

Figure 5: Final Deformation In Camshaft

5. Results and Conclusion

The vibration analysis of the camshaft is done and 6 mode shapes for each model are obtained. The minimum natural frequency that obtained is 11735Hz corresponding to the material i.e. EN24. So the material that has the minimum frequency and the minimum deformation is EN24. Which is in the safe range according to the design analysis?

5.1 Conclusion

According to the analysis work presented in the work the various materials been tested analytically in the ANSYS software according to the reports generated the materials have shown the various deformation limits and frequencies the material which is having the minimum deformation and the minimum frequency is comes out to be EN24 hence the camshaft made from this material have the design limits in the safe range

Table 4: Experimental results for different materials

	EN24
Mode	Frequency [Hz]
1.	11735
2.	11802
3.	12083
4.	12114
5.	12157
6.	12202

	EN8D
Mode	Frequency [Hz]
1.	16032
2.	16133
3.	16506
4.	16548
5.	16643
6.	16712

Cast iron	
Mode	Frequency [Hz]
1.	12122
2.	12193
3.	12480
4.	12512
5.	12566
6.	12614

	Billet steel
Mode	Frequency [Hz]
1.	15646
2.	15744
3.	16108
4.	16149
5.	16242
6.	16309

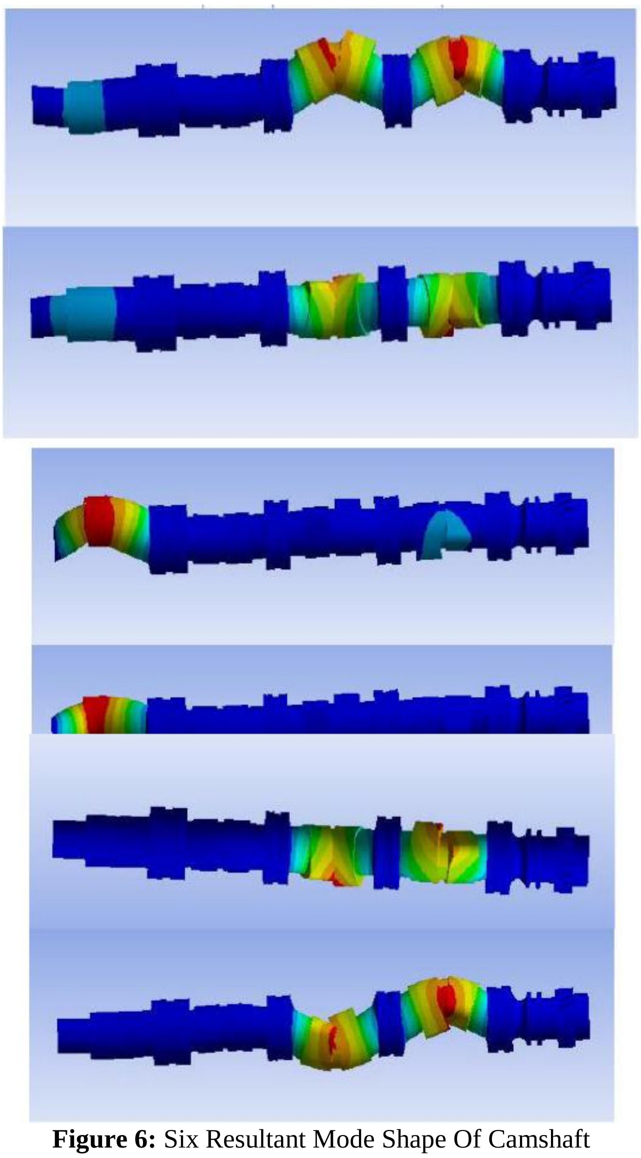

Figure 6: Six Resultant Mode Shape Of Camshaft

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