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FEA and Material Optimization ofCamshaft

M. Harika Chowdary, B. Bhargav Dinesh, M. Shakil Kumar, V.Chenna Reddy

Department of Mechanical Engineering, Godavari Institute of Engineering and Technology(A), JNTUK, Kakinada.

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ABSTRACT

A camshaft is a rotating element in an IC engine. It is situated either in the head of the engine or lower back of the engine. A camshaft is driven by the crankshaft by means of the timing gears or timing chains or a D.C motor. A camshaft is a metal rod which has lobes mounted on it. These lobes convert rotary motion of the rod into reciprocating motion of the inlet and exhaust valves.

The performance of camshaft mainly depends upon the proper design and material used in camshaft. It is very important to select proper material for camshaft by which efficiency of IC engine can be improved. The various materials used for camshaft are (CS840, C55Mn75, 40Ni 3Cr 65Mo 55). The project is focused on selecting a better material for camshaft by performing finite element analysis.This project studies variation of stresses on the camshaft for different materials. There will be a judgement after comparing the results to find a better material for camshaft. The cad model of camshaft is prepared using SOLID WORKS 2021 SP2.0, the cad model will be simulated in ANSYS workbench R21 for Structural analysis (equivalent stress, equivalent elastic strain, total deformation) and Modal analysis (frequency, deformation).

KEYWORDS: camshaft, Chilled Cast Iron, CS840r

1. INTRODUCTION

A camshaft is a main component in an IC engine. It is a rotating element in a valve train assembly [1]. The purpose of the camshaft is to provide motion to the valves. The camshaft which is driven by the crankshaft via timing chain or timing gears is mounted with lobes called cams. The cams have nose and flank. One end of the camshaft follows the contour of the cam and the other is connected to the valve. The valve is in closed position when the rocker arm is on the heel of the lobe. The valve gradually when the rockerarm follows the opening ramp and the valve is at its peak lift. The camshaft has several lobes called cams they cause the valves to open and close accordingly. The camshaft is driven by the crankshaft by means of a timing chain or gear train. The rockerarm is in continuous contact with the cam, as the camshaft rotates the load continuously varies this leads to the development of fatigue in the camshaft[2]. These fatigue loads cause deformation and bending of the camshaft.

The use of camshaft is very lively in every IC engine except for those that use electronically operated valves. But heavy-duty vehicles and high-performance engines still use camshafts for their reliability[3]. There may one or more camshafts to operate the valves separately. In V-type engines there maybe one or two camshafts per bank. Some heavy-duty engines use D.C motors to drive the camshaft. The camshafts are usually situated in the head called over-head camshafts to avoid additional weight of push rods. There maybe two or more lobes per span depending on number valves per cylinder.

The cams are timed with respect to the position of the piston inorder to achieve proper combustion the valves are to be operated perfectly. If the camshaft is deformed there will be an error in the operation of valves which results in reduced performance engine. So, it is recommended to choose wisely which material to use for camshafts. In order to withstand the fatigue a camshaft should be made material of materials that possess high tensile and yield strength along with hardness.

2. REALATED WORK

The material currently under use to make camshafts is chilled cast iron. Chilled cast iron is known for its wear resistance and tensile strength which are major factors to consider to select the material to use to make camshafts. Chilled cast camshafts have been under use for long time. Cast iron is used to make camshafts because these components have lower vibrations. There are many citations that show that steels are better materials to make camshafts. Steel camshafts have better performance when it matches the material of follower.

When it comes to vibrations, they play major role in selecting the material for camshaft. It is nominal that camshaft has less nodal vibration for better performance. The camshafts made of chilled cast iron starts to deform at lesser frequencies when compared to that of the steels. And also, steels possess good impact strength when compared to cast iron.During static structural analysis on a diesel engine camshaft EN 8D (Mild Steel) can be used as an alternative to make camshafts[4]. EN 8D is the material that can be used to manufacture camshafts if one has to compromise between performance and weight of the component[5].

3. PROPOSED WORK

In this we are proposing a better alternative material to make camshafts to increase their performance. We are simulating the camshaft of a 3-cylinder 796cc SOHC engine. The simulation involves static structural and modal analysis. The cad model is designed in SOLID WORKS 2021 SP2.0, the camshaft has two lobes for each cylinder. It is belt driven and has 4 bearing supports. The cad model is then imported to ANSYS workbench for simulation, to perform simulation required properties of metals have to be set in. It mainly requires young's modulus, density, and poison's ratio of the material. The simulation also requires boundary conditions such as cylindrical supports, forces acting on the camshaft. The forces acting on the camshaft are calculated and all this comes under pre-processing. The cad model is meshed, the meshing elements are tetrahedral. Materials used in the simulation are CS 840, C55Mn75, 40Ni3Cr65Mo55 these materials are chosen for high tensile strength and hardness, ideal properties for a material to make camshafts. In solution phase the fixed supports are given, forces are applied. The rotational velocity is given as 230 rad/s. In post-processing the mode of analysis selected are, they are equivalent stress, equivalent strain and total deformation. In modal analysis we observe the natural frequencies and total deformation due vibrations at different nodes. The results of this simulation are compared to that of chilled cast iron to choose the better material.

Table 1: specifications of camshaft

BASE DIAMETER	28.6 mm
DIA OF JOURNAL	50 mm
TOTAL CAM LIFT	7.65 mm
WIDTH OF CAM	18 mm
HEIGHT OF CAM	41.3 mm

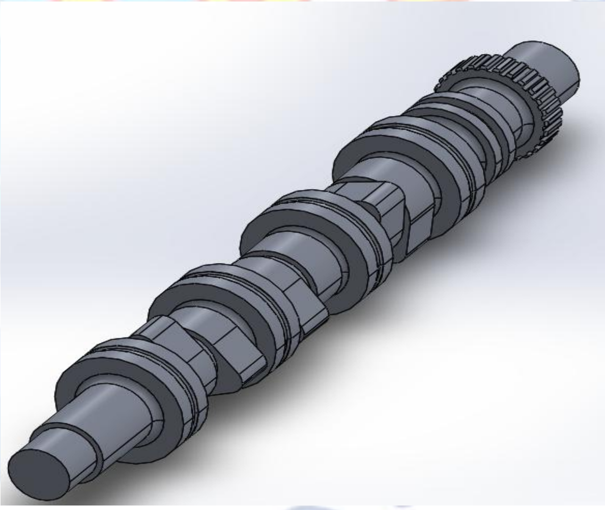


Figure 1: Designed camshaft in Solidworks

Table 2: mechanical properties of materials.

	CS 840	C55 MN75	40NI 2CR 65MO55	CAST IRON
Tensile strength(pa)	8.4e+08	5.6e+8	1.012e+09	5.8e+8
Yield strength(pa)	7e+08	5.6e+8	7.85e+08	4.8e+8

Youngs modulus(pa)	2.1e+11	2.1e+11	2.1e+11	1.7e+11
Poisson's ratio	0.28	0.3	0.3	0.26
Density(kg/m3)	7850	7850	8200	7150

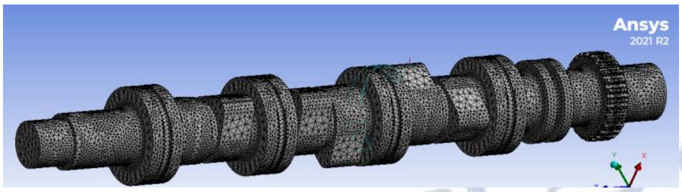


Fig 2: camshaft after meshing

Table 3: Statistics of meshing

Nodes	53335
Elements	30035

There are some numerical calculations applied as constraints in static structural and modal analysis section. The calculations are mentioned below

1. Inertia force of Valve (F_{i-v}) = $-A_i\times$ Mass of the valve

= -191.861 × 0.100

= -19.1861 N

Where $-A_i$ is the valve acceleration

2. Spring elastic force (F_{EV}) = $H_v\times$ K

Let H_v=0 mm,K=18 n/mm, F_{ev}=0 N

$F_{NET}=F_{EV}-F_{i-v}$ = 19.186 N

Where H_v=height of the valve,K=stiffness of spring

3.Force on camshaft due to rocker arm (F_R)

$F_R = F_V \times (r1/r2)$

= 19.861 × (39.3/36.3)

= 21.50 N

Where (r1/r2) is rocker arm ratio

4. Valve acceleration (A_V)= 191.861 m/s² = (γ)

Angular acceleration of the rocker $=\alpha=\psi$

$= \alpha\times\gamma$

$=60.82 \text{ X } 10^{-3} \text{ X } 191.861$

=11.668 rad/s²

5. Inertia of the rocker arm=0.0003kg/m²

Moment of rocker arm (M_r)= inertia X torque

= (-1) X (I) X (ψ)

Thus M_r=0; F_r=0 where I=0.0003, ψ=0 at opening

6. volume calculation:

$X_p=r(1-\cos\theta +n-\sqrt{(n^2-\sin^2 \theta)})$

n=3

clearance ratio=9:2

$R_c=(V_S+V_C)/V_C$

$V_S=\pi/4 \times d^2 \times L$

$= \pi/4 X\times (66.5 \times 10^{-3}) \times 72\times10^{-3}$

$= 2.499 \times 10^{-4}$ M³

$V_C =(V_S+V_C)/R_C=6.857\times 10^{-5}$ M³

$V_T= V_C+V_S=3.18515\times10^{-9}$ M³

7. Gas force:

F_G=valve head area× gas pressure

$=\pi/4 \times d^2 \times P$

$D_p=0.435\times d=0.435\times66.5$

= 28.97 mm

$F_G =\pi/4 \times 28.97\times10^{-3}\times6.05\times10^5$

= 398.788 ≅ 400 N

8. Force on camshaft due to rocker arm:

$F=F_g\times(r1/r2)$

=400×(39.3/36.3)

=433 N

F_{net}= 433-21.50=411.5 N

Then, in the Static Structure section, select constraints such as force, cylinder support, and solid support. After specifying the constraints in the Static Structure section, click on Solve. Then, in the Solution pane, select Total Deformation, Equivalent Stress, and Strain. After making your selection, click on evaluate all results. Before the meshing process, select a material in the Materials section of the outline tree.

Repeat the process for the rest of the material. In the modal analysis, it was necessary to find the total deformation and frequency Along with modes .in modal analysis same procedure is involved as mentioned in static structural analysis

post performing of static structural and modal analysis, we have to tabulate the readings and make a comparison of 3 materials with cast iron. then we have to select the suitable material for camshaft

4. RESULTS

In this, the results of different materials from the simulation are compared against that of the standard camshaft material (chilled cast iron) and also compared among themselves. The forces acting are considered and taken as total load on camshaft. The behavior of the camshaft under total load for different material are observed and compared against the behavior of camshaft made chilled cast iron. The equivalent strain, equivalent stress and total deformation for camshafts of different materials under total load are studied in static structural analysis. In modal analysis, natural frequency and total deformation of the camshaft at different nodes is observed.

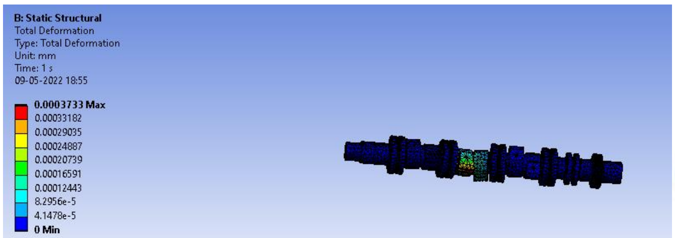


Fig 3: Total deformation for CS840

Table 4: Result of structural analysis

		CS 840	C55 Mn75	40Ni 2Cr 65MO55	Cast iron
Deformation(mm)	**Min**	0	0	0	0
	Max	0.00037	0.004	0.0046	0.00045
Strain (mm/mm)	**Min**	6.84e-9	1.9e-7	2.08e-7	7.54e-9
	Max	1.79e-5	.0001	0.00012	2.22e-5
Stress (Mpa)	**Min**	0.00031	0.024	0.025	0.00036
	Max	3.7575	25.33	26.635	3.7783

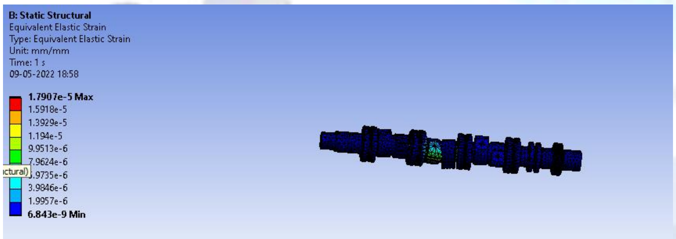


Fig 4: Equivalent elastic strain for CS 840

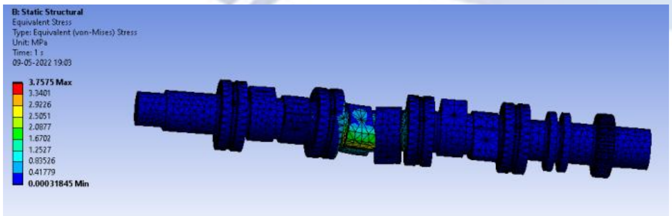


Fig 5: Equivalent stress for CS 840

We observed that CS 840's performance is significantly higher than that of chilled cast iron for same conditions. Under same operating conditions chilled cast iron's performance is comparatively lesser than CS 840. Camshaft made of chilled cast iron deformed more than the camshafts made of CS 840, and also its equivalent stress and equivalent strain are much lesser than chilled iron.

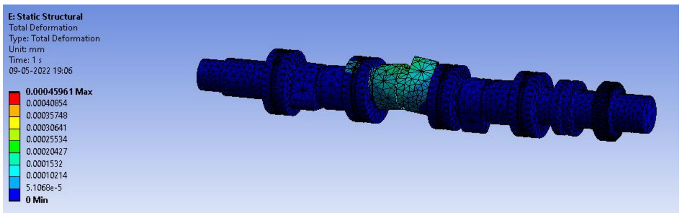


Fig 6: Total deformation for Cast iron

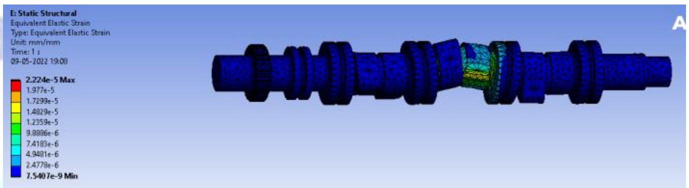


Fig 7: Equivalent elastic strain for Cast iron

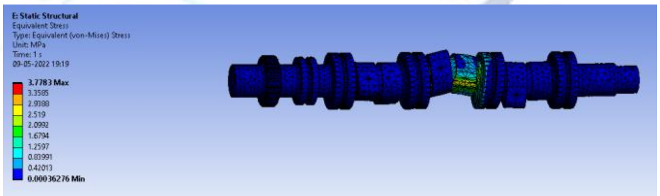


Fig 8: Equivalent stress for Cast iron

In modal analysis, natural frequency and total deformation of the camshaft at different nodes is observed. We observed that CS 840's performance is significantly higher than that of chilled cast iron for same conditions. Under same operating conditions chilled cast iron's performance is comparatively lesser than CS 840. Camshaft made of chilled cast iron deformed more than the camshafts made of CS 840, and also its equivalent stress and equivalent strain are much lesser than chilled iron. In modal analysis, while the camshaft made of chilled cast iron deformed at lower frequencies, the camshaft made of CS 840 only started to deform at significantly higher frequencies proving that steel camshafts can withstand higher frequencies without deforming as shown.

Table 5: modal analysis result for cs840

mode	Frequency (Hz)	Total deformation(mm)
1	2118.8	80.808
2	2121.3	80.823
3	5293.9	124.46
4	5299.2	124.5
5	6665.5	89.121
6	9180.7	29.145

Table 6: modal analysis result for cast iron

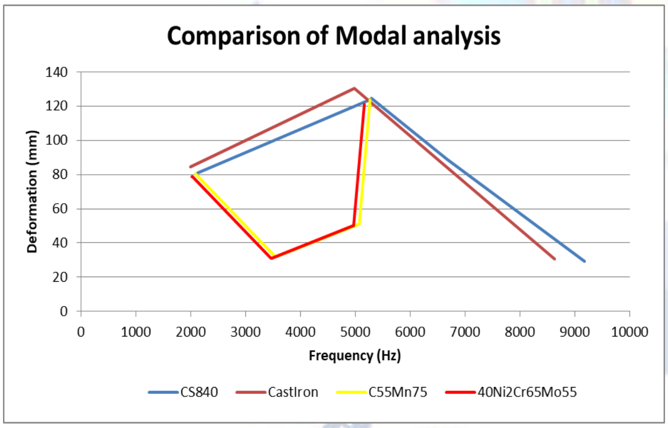
mode	Frequency (Hz)	Total deformation(mm)
1	1991.3	84.655
2	1993.6	84.67
3	4978.7	130.35
4	4983.5	130.39
5	6333.3	93.381
6	8628.8	30.594

Table 7: modal analysis result for C55 Mn75

mode	Frequency (Hz)	Total deformation(mm)
1	2078.6	80.609
2	2078.7	80.607
3	3542.3	31.787
4	3545.5	31.844
5	5075.4	51.106
6	5271.6	123.73

Table 8: modal analysis result for 40 Ni 2Cr 65MO55

mode	Frequency (Hz)	Total deformation(mm)
1	2023.5	78.87
2	2032.6	78.867
3	3465.2	31.101
4	3468.3	31.157
5	4965.9	50.003
6	5157.4	121.06



Graph 1: Comparison of modal analysis

5. CONCLUSION

In this we suggested an efficient material as alternative for chilled cast iron to make camshafts. Steels are proven to be better camshaft materials as they can withstand higher stresses and deform less than the camshafts made of chilled cast iron under same circumstances. Using steels to make camshaft increases its performance and also increases its life cycle. When compared amongst chilled cast iron and CS 840, CS 840 has shown better behavior than the other. So, camshafts behavior can be optimized when they are made of steel

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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