Advances and Applications in Mathematical Sciences
Volume 20, Issue 10, August 2021, Pages 2185-2196
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MODELLING AND FATIGUE ANALYSIS OF THE COMPOSITE MATERIAL CAMSHAFT USING FINITE ELEMENT METHOD

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Abstract

The opening and closing of the two valves are regulated by the camshaft and its associated parts. Push rods, rocker arms, valve springs and tappets are the related elements. Composite materials are widely used in the field of engineering today. The general characteristics of composite materials are considered to be the reason why they are used in automotive applications. Camshafts spin at high velocities, creating machine vibrations. Owing to the touch of the plunger on the cam, camshafts are often subject to varying contact fatigue loads. Due to these fluctuations, vibration and fatigue failures occur on the shaft. Hence fatigue analysis need to be carried out on the camshafts to security and life determination of the member. Finite element analysis comprehensively provide the results for the camshaft member under irrational and fatigue loading. 3D-model of the camshaft is created using modeling software CATIA and analysis done in ANSYS with different materials composite material, alloy steel and cast iron. In this paper, the static analysis and fatigue analysis done to conclude the deformation, stresses, strains and fatigue analysis is to estimate the life of the component, and factor of safety of each component. We conclude that for better performance of camshaft and for long fatigue life, composite material give good results for factor of safety and weight of the component.

I. Introduction

In internal combustion engines, camshaft are used and are subject to millions of different stress cycles that lead to fatigue failure. The camshaft is driven through a series of gears called idler gears and timing gears by the engine's crankshaft. The gears cause the rotation of the camshaft to

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2010 Mathematics Subject Classification: 65-06, 65DXX.
Keywords: Camshaft, Composite material, Finite element, Static analysis, Fatigue analysis.
Received February 4, 2021; Accepted April 7, 2021

correspond or be in time with the rotation of the crankshaft. Under cyclic bending and torsion, the camshaft fatigue fracture easily occurs at stress concentration. For tests with cyclic completely reversed and mean stress, an energy-based fatigue criterion was established in the paper [1]. In order to derive an equivalent stress intensity factor (K) for stress concentrations in components, the approach uses linear elastic finite element analysis. K is measured without the part being cracked: the stress field is tested around the maximum stress point and compared with that of a regular center-cracked plate [2]. Many parameters, such as geometry (notches), load (static cyclic-stochastic, proportional-non-proportional), material (ductile semi ductile-brittle), surface roughness, surface treatment, temperature, and surface roughness, affect the fatigue behavior of system components etc. [3]. The mathematical ad physical relationship retains the definition of fatigue life behavior of the stress-strain curves of the materials [4].

Marine structures are often built with damage tolerance, such as ships and offshore platforms, and this design philosophy includes precise prediction of the fatigue crack propagation process [5]. The portion of fatigue approaches and study in fiber-reinforced composite materials that researchers worldwide predict fatigue life I composite material have done [6]. Fatigue failure one of most common modes failure in metal fatigue occurs when fluctuating stress and strain metals [7]. Experienced loading complexes over a long period of operation. In order to ensure the safety and reliability of components, accurate fatigue life research is very important. [8]. Demonstration of a hybrid glass/carbon fibre composite wind turbine blade spar cap/root joint was designed, manufactured and tested statically and dynamically. The specific composite structure combines triaxial and biaxial E-glass and carbon fibres embedded in a powder epoxy matrix [9]. Most materials used in an automotive substructure, such as a chassis system, exhibit combined hardening behavior, and in order to accurately predict the fatigue life, it is important to capture this behavior in the CAE model [10].

Sample observation of small cracks on the surfaces of fatigued specimens subjected to multi axial loads. Based on the cracking analysis it was found that the shear damage mechanism was shown by the aluminium alloy and low-alloy steels, while the austenitic steel showed the tensile damage mechanism [11]. Collaboration of fatigue, engineering with FEA, that is how

FEA used to finding results of fatigue behaviour of material with FEA [12]. Three point bending fatigue test performed ad constructed Morrow Haigh diagram experimental study and die life estimated according to stress amplitude and mean stress values [13]. Formulate a numerical method for modeling the accumulation of fatigue damage in essential components of reinforced-concrete industrial buildings [15]. After study of the literature, this paper has been written with following objectives:

1. To study the behaviour of camshaft under cyclic loading condition for different materials.

2. Compare the results for different parameters with different materials and choose best material.

II. Methodology and Analysis Procedure

A. Methodology carried out in this research paper.

1. First conventional camshaft is modeled by using modeling software and then imported into analysis software.

2. Design calculation of cam shaft are performed.

3. Fatigue analysis of existing camshaft to study deformation, stress, factor of safety and life.

4. Same camshaft having same dimensions is modeled and fatigue analysis is completed with the change in the material.

5. Comparative study of the results is carried out to identify suitability of the material.

B. Procedure for conducting numerical analysis.

(1) Finite Element Modeling:

In this research, the analysis was conducted on a camshaft. Camshaft was modeled with CATIA V5 software. The model can be created in the pre-processor or imported via a neutral file format (IGES, STEP, ACIS, Para solid, DXF,) from another CAD drafting package. After that it imported on Ansys workbench for analysis which you want next to result (preprocessor-postprocessor) results.

(2) Applying Mesh:

Mesh generation is the method of splitting the spectrum of analysis into a number of different components or finite elements. The finer the mesh, the better the results, but the time for analysis is longer. Therefore a balance is typically made between accuracy and solution speed. The mesh can be manually produced, such as the one on the right, or automatically generated, like the one below. You will find that the elements are smaller at the joint in the manually generated mesh. This is known as mesh refinement, and at geometric discontinuity it allows the stresses to be recorded. For models with any degree of geometric complexity, manual meshing is a long and tedious operation, but with useful instruments appearing in pre-processors, the task is becoming easier. The mesh is developed by a mesh motor automatically; the only requirement is to define the mesh density along the sedges of the model.

(3) Applying loads and Boundary conditions:

In a stress (displacement) analysis, the load may be in the form of a point load, a pressure or a displacement, a temperature or a heat flux in a thermal analysis and a fluid pressure or velocity in a fluid analysis. It is possible to add loads to a point, an edge, a surface or even a complete body. The loads should be in the same units as the stated model geometry and material properties.

(4) Solution:

Logically, the Finite Element solver can be split into three key parts: the presolver, the mathematical engine, and the post-solver. The pre-solver reads and formulates the mathematical representation of the model in the model established by the preprocessor.

(5) Post Processing:

Read and interpret the outcomes of the study here. If frequency analysis is needed, they can be shown in the form of a table, a contour map, deformed component shape or mode shapes and natural frequencies. Post-processors have an animation service that generates animation and gives life to your model. For structural type issues, contour plots are typically the most productive way to display data. Slices can be made to facilitate the viewing of internal stress patterns via 3D models. All postprocessors now include stress and strain calculation in any of the directions of x, y or z, or indeed in a direction at an angle to the coordinate axes. It is also possible to map the main stresses and strains or if applicable, the yield stresses and strains in accordance with the main failure theories (Von-misses, St. Venant, Tresca etc.).

C. Specifications of Engine.

Power = 74 H.P.

Speed = 4000 RPM

Torque (max) = 190 N-m at 2000 RPM

Cylinder volume = 1258 CC

Max. Pressure = 140 bar

Bore = 69.9 mm

Stroke = 82 mm

Compression ratio = 17:1

Inlet valve opens = 25° Before TDC

Inlet valve closes = 25° After BDC

Exhaust valve opens = 50° Before BDC

Exhaust valve closes = 15° After TD

III. Results and Discussion

In this section the results are presented for different materials.

Total effective force on cam lobe Tip = Gas force acting on camshaft + Pushrod tappet inertia force + Valve inertia force = 825N

A. Fatigue analysis of camshaft using Ansys analysis software.

(1) Material properties given to Grey cast iron camshaft:

Density $= 7200 \mathrm{kg/m}^3$

Young's Modulus = 66000MPa

Poisson's Ratio = 0.3

Bulk Modulus = 5.5E+10Pa

Shear Modulus = 2.5385E +10 Pa

Tensile Yield Strength = 98 MPa

Compressive Yield Strength = 500 MPa

Tensile Ultimate Strength = 150 MPa

Compressive Ultimate Strength = 500 MPa

(2) Meshing:

Mesh statistics are as follow:

1. Minimum edge length: 1.7811 x 10^-2 mm
2. No. of element: 22475
3. No. of nodes: 59053

Mesh quality check:

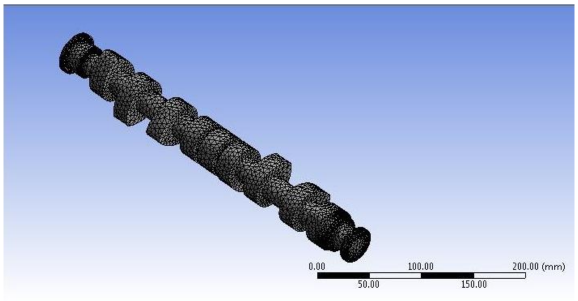


Figure1. Mesh model.

Table I. Mesh Quality Check.

Sr. no.	Mesh quality parameter	Required	Achieved
1	Skewness	<0.7	0.55
2	Jacobian	Ideal value 1	1
3	Warping	<30, Ideal value	9
4	Aspect ratio	<5	5
5	Orthogonal quality	> 1	0.6079

(3) Boundary Conditions:

For next step applied boundary condition like a fixed support, forces in x, y, z direction and any external moments etc. in fluid analysis apply fluid forces parameters like velocity, acceleration, energy equations.

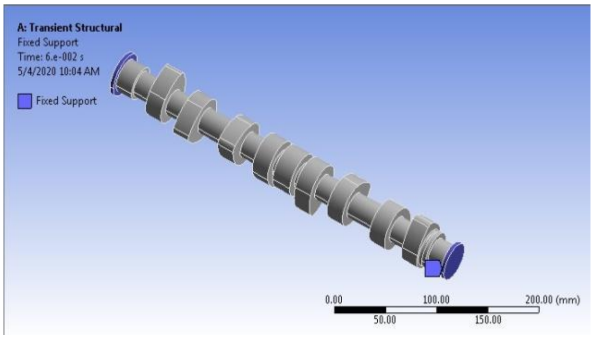
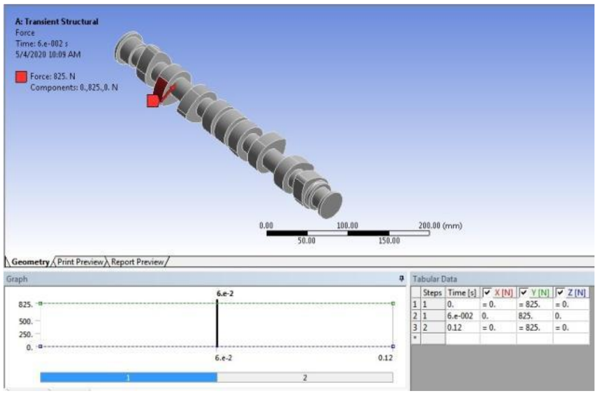


Figure 2. Fixed support.



	Steps	Time [s]	☑ X [N]	☑ Y [N]	☑ Z [N]
1	1	0.	= 0.	= 825.	= 0.
2	1	6.e-002	0.	825.	0.
3	2	0.12	= 0.	= 825.	= 0.
*					

Figure 3. External force.

B. Results for deformation, Von-Mises stresses and Factor of safety.

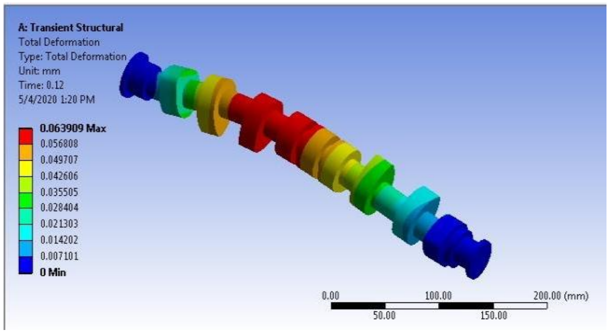


Figure 4. Total deformation.

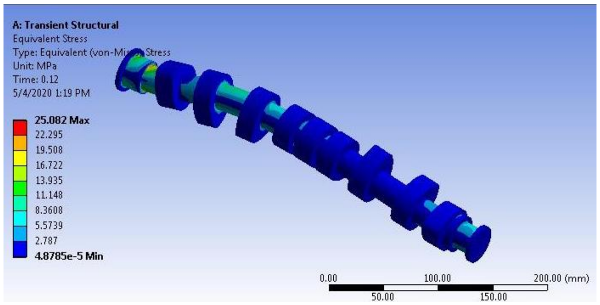


Figure 5. Von-Mises Stresses.

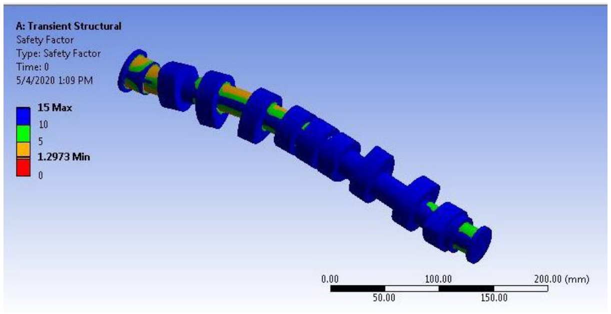


Figure 6. Factor of safety.

C. Design of Camshaft for optimization.

3D camshaft modeling is performed in CAD software after analysis of the current method. Analytical concept estimation of the current device is also performed. The design of that optimization system will begin. System optimization will be carried out according to one of the following situations:

1. Changing dimensions and keeping material same given.
2. Keeping same dimensions and changing material of components,
3. Changing both material and dimensions of component.

Approach:

There are various alternate materials like alloy steel, various composite material etc. Lower weight and high power, which can therefore be used for camshaft. Hence, in this case, all the dimensions are kept same and material of the component is changed.

Table III. Various Materials Properties for fatigue analysis of camshaft.

Sr. No	Material	Density (Kg/mm3)	Young's modulus (GPa)	Possion's Ratio
1	Alloy steel	7830	190	0.27
2	Composite material	2300	101	0.3

D. Alloy Steel

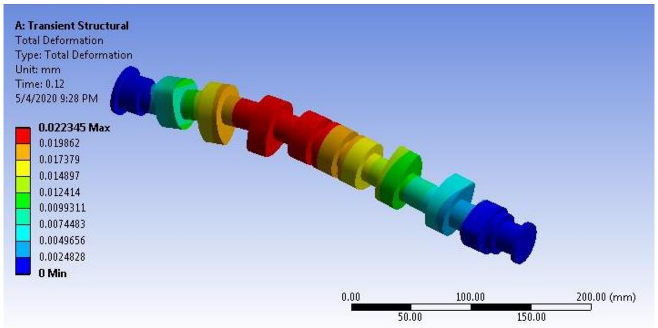


Figure 7. Total deformation.

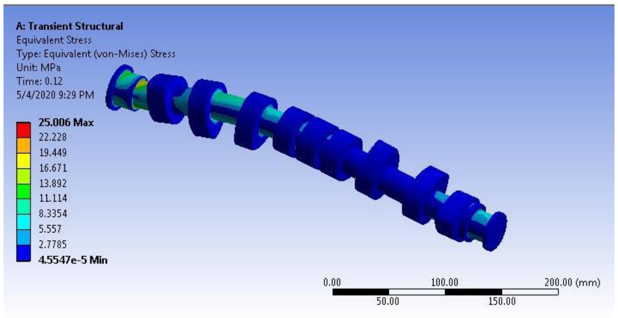


Figure 8. Von-Mises Stresses.

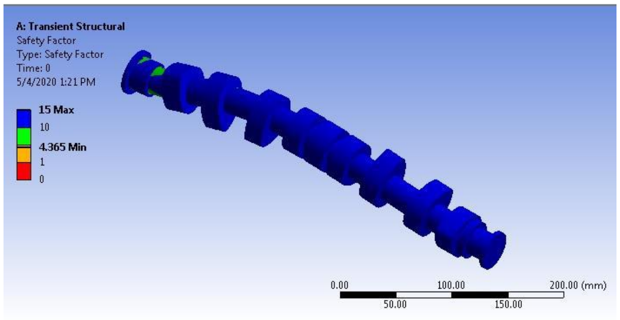


Figure 9. Factor of safety.

E. Composite Material.

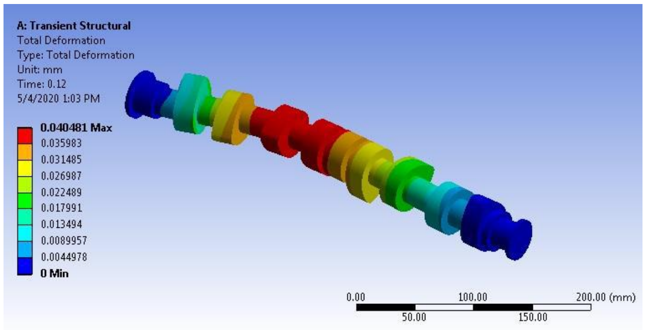


Figure 10. Total deformation.

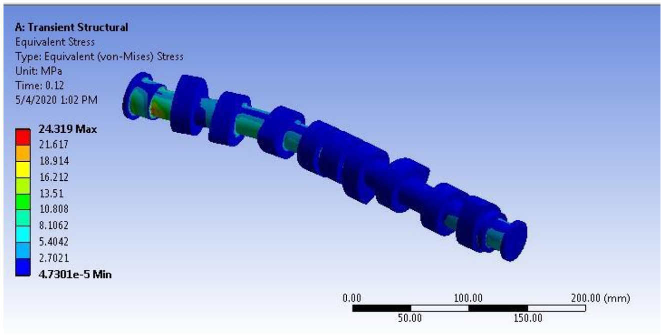


Figure 11. Von-Mises Stresses.

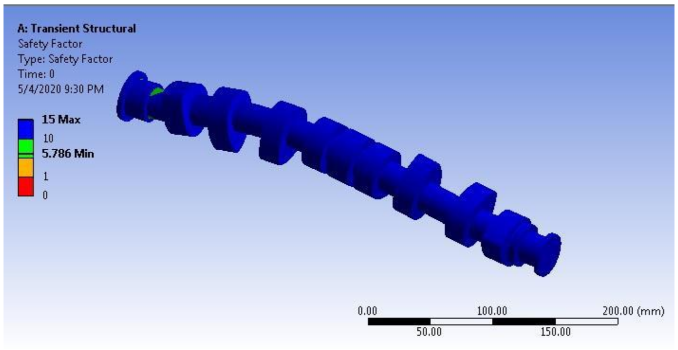


Figure 12. Factor of safety.

Table IIIII. Summary of Results for Different Materials.

Sr No.	Parameter	CI	Composite material	Alloy steel
1	Von mises stress (MPa)	25.082	24.319	25.006
2	Deformation (mm)	0.00639	0.04048	0.02234
3	Factor of safety	1.2973	5.786	4.365
4	Weight	2.744	0.87668	2.9845

From above ANSYS results, it is observed that there is a slight change of Von-Mises stress for both the materials for same loading condition and same physical properties. But weight and factor of safety of composite material are better as compared with cast iron and Alloy steel.

IV. Conclusions

Camshaft is one of the key components of internal combustion engines used in automobiles and other applications. From the above results, we conclude that for better performance of camshaft and for long fatigue life, composite material give good results for factor of safety and weight of the component. Hence, composite materials are good alternate material for camshaft.

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