Geometrical Modelling and Analysis of Two Wheeler Camshaft by using Finite Element Method

M. G Nitish[1] and M. Sangamesh[2]

Department of Mechanical Engineering, PES University, Bengaluru, Karnataka, India

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Abstract: *A camshaft is a rotating cylindrical shaft used to regulate the fuel in an internal combustion engine. In internal combustion engines with pistons, the camshafts are used to operate poppet valves. Camshafts are responsible for accurately-timed fuel injections required by internal combustion engines. Camshafts are rotating components with critical road; these exact values are needed to be determining to avoid failure in camshaft. A Small variation in the camshaft angle or small amount of wear leads to improper combustion of fuel mixture in chamber. The material used for automobile camshaft is chilled cast iron and it has comparatively better mechanically properties when compared with similar segment metals. But in this modern world it's all about competition and more efficiency. In the present work, other two different materials is considered, MMC composite (Al-Sic) and Billet Steel. A geometry with exact dimension of two wheeler camshaft is considered and using Solidworks it is designed, the finite element analysis is carried out using ANSYS maximum stress, fluctuating load (harmonic loading) is tested for all the three materials with respective properties and we can observe when compared to Composite and world-wide used Chilled Cast iron, billet steel has better results and less stresses developed.*

Keywords: Camshaft, Chilled Cast Iron, Composite, Billet Steel.

I. INTRODUCTION

A Camshaft is a shaft to which a cam is fastened or of which a cam forms an integral part of the engine. Cam is a mechanical member for transmitting a desired motion to a follower by direct contact. Camshaft is the brain of the engine that includes cam lobes, bearing journals, and a thrust face to prevent fore and after motion of the camshaft. The main function of the camshaft is to operate valves and fuel injectors in the engine. The camshaft and its associated parts control the opening and closing of the two valves. The cam is usually driven by timing gears, chains, or belts located at the front of the engine. The gear or sprocket on the camshaft has twice as many teeth, or notches, as the one on the crankshaft. This results in two crankshaft revolutions for each revolution of the camshaft. The camshaft turns at one-half the crankshaft speed in all four stroke cycle engines. Camshaft has huge history in automobile industry; Fiat in 1980's started using Chilled Iron of Grade17 Cast Iron (with 1% of chrome). Some might refer to the camshaft as the brain or heart of the engine. It determines when, how long, and how far the valves open and close in relation to the pistons. For every two revolutions of the crankshaft the camshaft rotates one revolution. On most overhead valve engines there are two main types of camshafts, either a flat tappet camshaft or a roller camshaft. Whether it's your first time building an engine or you're just looking for a performance upgrade, understanding camshaft specifications and design is a must.

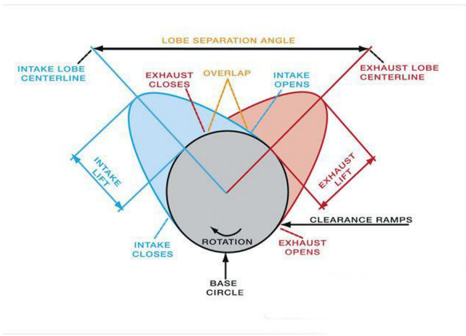


Fig. 1 – Camshaft

II. LITERATURE SURVEY

Nipane et. al. (2015) [1] The paper is devoted to study of modelling and fatigue analysis of 4 wheeler camshaft. The objective of the project is to modelling and fatigue analysis of metal matrix composite (MMC) camshaft. It mainly focuses on replacement of Cast iron camshaft to Metal Matrix Composite. Vijaya Ramnath et. al. (2014) [2] Aluminium matrix composites (AMCs) are potential materials for various applications due to their good physical and mechanical properties. This paper presents the overview of the effect of addition on different reinforcements in aluminium alloy highlighting their merits and demerits. Anthony Macke et. al. (2012) [3] Offer the Automotive Industry an Opportunity to Reduce Vehicle Weight, Improve Performance. C.Baron et. al. (2017) [4] In this work we compiled the key properties melting point, bulk modulus, shear modulus, Young's modulus, density, hardness. I. Ucun et. al. (2006) [5] Fracture analysis of the camshaft of an automobile engine is carried out. A Stress analysis is carried out by finite element technique for determination of high stressed region of the camshaft. Zeyaullah Ansari et. al. (2017) [6]. The present work we are composed of Automobile camshaft by Numerical Calculations there after it is planned by utilizing Modelling software PRO-E and CAE Analysis is done in ANSYS by differing material- AL Metal Matrix Composite (ALMMC) to research the deformation, stress and strain developed on camshaft. Petr Hejma et. al. (2016) [7]. In this article the configuration of a mechanism, comprising a flat faced follower, which is pressed to the surface of a radial cam by the coil spring, is studied. There will be proposed a methodology for the calculation of torque according to the desired angular velocity of the cam. Uma Mahesh et. al. (2015) [8]. The present work is on the design of Automobile camshaft by Numerical Calculations there after it is Designed by using modelling software CATIA and CAE(Structural) Analysis is carried out in ANSYS-WORKBENCH by varying three different materials Cast-iron, Carbon steel and Al-MMC to investigate which material will give best performance for camshaft. S.T Mavhungu et. al. (2017) [9], The Automotive industry is subjected to increasingly restrict fuel economy requirements by consumers demanding improved comforts and safety. To achieve these requirements Aluminium Metal Matrix Composite is used. This ultimately leads to the development of advances material parts with improved performance and efficiency. J. Michalski, J. Marszalek, K. Kubiak [10] The main objective of this paper is to study and experimentally quantify the cam and follower wear mechanisms of a diesel direct valve-gear.

A. Problem Statement

The Cam Shaft which is used in the automobile will be usually made of the metal (Chilled cast iron with 1% chrome), as the metals have greater weight and have lesser wear resistance and due to which it might get corroded, loose its strength, wear out very soon, and we know metal has higher rate of stress strain deformation. So Composite material, Al-Metal Matrix Composite is selected as a replacement and analysed to check whether it can be replaced with existing metals used in Automobiles. As composite materials have high strength to weight ratio, higher wear resistance more advantages when compared to metals.

III.GEOMETRICAL MODELLING OF CAMSHAFT

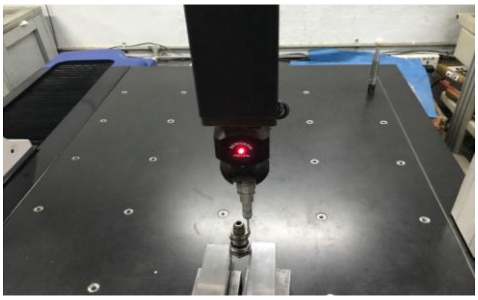
A. *Modelling of Camshaft*

Camshaft is one of the important functioning part of any engine, it plays the important role in complete combustion of 4Stoke Engine. Typically, for present study "Camshaft of Honda Unicorn 150cc (4 Stroke IC engine) is used". This Camshaft is used for dissertation work to carryout study on static structural analysis.

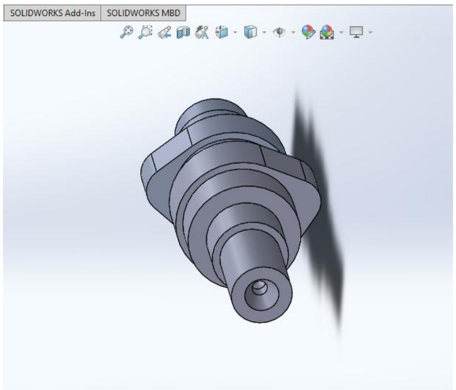
Fig. Camshaft of Two Wheeler Engine

In this work, Finite element modelling is used to carryout analysis on camshaft. In this work three materials are considered for the material optimization of the camshaft, Chilled Cast iron which is existing Camshaft material is Compared with the similar mechanical properties material like Aluminum Silicon Carbide which is a composite material which is the latest trending available material for automotive industry, and Billet Steel is Considered.

B. Measuring the Camshaft using CMM Machine



C. Modelling OF Camshaft using Solid Works



D. Mechanical Properties

i. Chilled Cast Iron

Young's Modulus	190000 Mpa
Poisson's Ratio	0.27
Bulk Modulus	158330 Mpa
Shear Modulus	74803 Mpa
Density	7300 kg/m^3
Tensile Strength	413.6 Mpa
Compressive Strength	140 Mpa
Yield Strength	275.7 Mpa
Thermal Expansion Co-efficient	3.24 /k Mpa
Thermal Conductivity	47 W/(m-k)
Specific Heat	510 J/(kg-k)

ii. Aluminium Silicon Carbide (63% of Al and 27% of SiC)

Young's Modulus	167000 Mpa
Poisson's Ratio	0.3
Bulk Modulus	139170 Mpa
Shear Modulus	64210 Mpa
Density	3100 kg/m^3
Tensile Strength	220 Mpa
Compressive Strength	118 Mpa
Yield Strength	140 Mpa
Thermal Expansion Co-efficient	0.22 /k
Thermal Conductivity	180 W/(m-k)
Specific Heat	808 J/(kg-k)

iii. Billet Steel

Young's Modulus	193000 Mpa
Poisson's Ratio	0.27
Bulk Modulus	75984.8 MPa
Shear Modulus	139868 Mpa
Density	8000 kg/m^3
Tensile Strength	500 Mpa
Compressive Strength	140 Mpa
Yield Strength	137.9 Mpa
Thermal Expansion Co-efficient	4.3 /k
Thermal Conductivity	16.3 W/(m-k)
Specific Heat	500 J/(kg-k)

IV. FINITE ELEMENT ANALYSIS

A. Meshing of Camshaft

After importing the geometric model to pre-processor software, the mesh is generated using HYPERMESH software. For the element size a mesh independence study is carried out hence three different element size is considered for the Camshaft and checked for variations in results. The FE model of a Camshaft is shown in Figure.

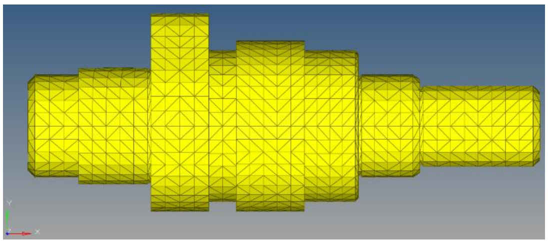


Figure 14 - Mesh Size 2mm

B. Static Structural Analysis

After completing the meshing in Hyper mesh the model is imported to NASTRAN for static structural analysis with required Boundary Conditions as mentioned below:

1. At circular ends of the camshaft, all 3 transitional (x, y and z) DOF are fixed and rotational DOF (Rx, Ry, and Rz) are free. Applying Fixed Support at ends.
2. At the cam lobe end bushing all 3 transitional (x, y and z) DOF are fixed and rotational DOF (Ry, Rz) are fixed but rotation about (Rx) is free as the camshaft tends to rotate about an axis.and the Load is acted upon the cam, is show in below figure and the pressure acting on it itself is considered as the load acting on the Camshaft.

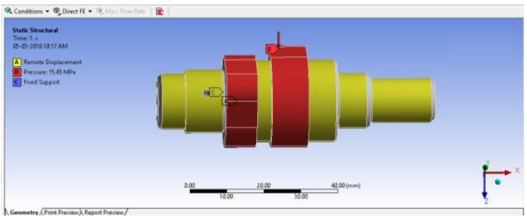
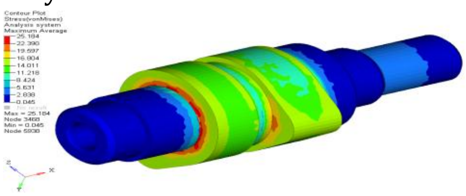


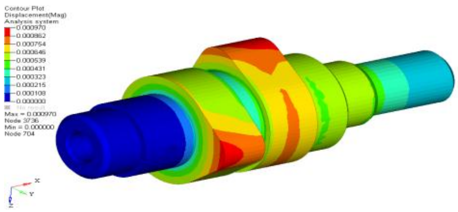
Figure 18: Force acting at cam lobe surface

Load acting on camshaft – Pressure of 15.45 Mpa is acting on the cam lobe surface (A static analysis can, however, include steady inertia loads, such gravity and rotational velocity, and time varying loads that can be approximated as static equivalent loads.)

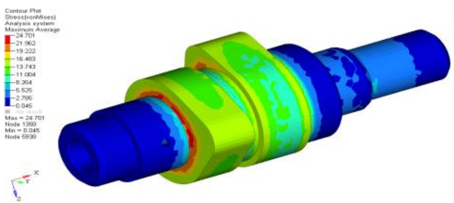
C. Static Analysis Results-



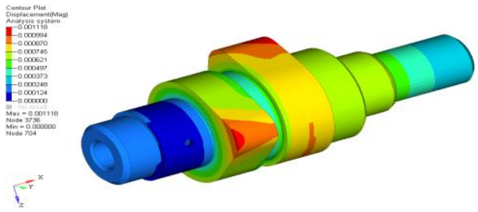
1.Chilled Cast Iron with mesh element size of 2mm – Von-misses stress on camshaft



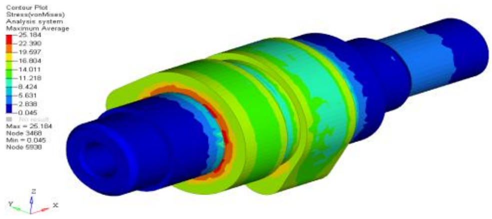
2.Chilled Cast Iron with mesh element size of 2mm- Total Deformation of camshaft



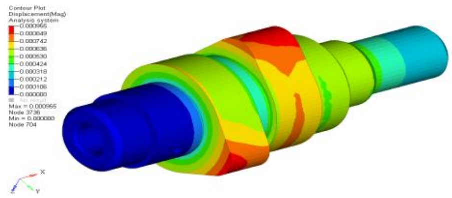
3.Aluminium Silicon carbide with mesh element size of 2mm – Von-misses stress on camshaft



4.Aluminum Silicon carbide with mesh element size of 2mm – Total Deformation of camshaft



5.Billet Steel with mesh element size of 2mm – Von-misses stress on camshaft



5.Billet Steel with mesh element size of 2mm – Total Deformation of camshaft

Static Stress Results of Chilled Cast Iron

Parameter	Stresses, Mpa	Deformation, mm
Maximum Stress	25.184	$9.70*10^{-3}$
Minimum Stress	0.045	0

Static Stress Results of Aluminium Silicon Carbide

Parameter	Stresses, Mpa	Deformation, mm
Maximum Stress	24.701	$1.11*10^{-3}$
Minimum Stress	0.046	0

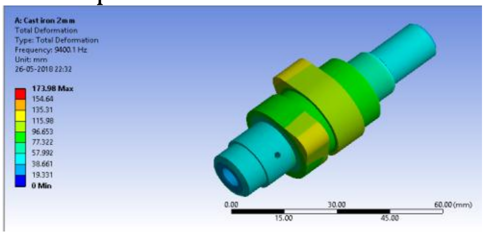
Static Stress of Billet Steel

Parameter	Stresses, Mpa	Deformation, mm
Maximum Stress	25.184	$9.55*10^{-3}$
Minimum Stress	0.045	0

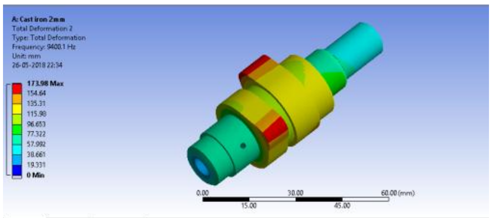
D. Modal Analysis

Modal analysis is used to determine the dynamic behaviour of a structure under steady state oscillatory motion, which is sinusoidal in nature. The modal parameters such as natural frequency, mode shapes and damping ratio of the structure are determined under dynamic loading conditions.

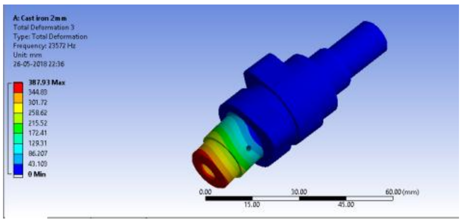
1. Mode Shape of Chilled Cast Iron



Mode Shape 1

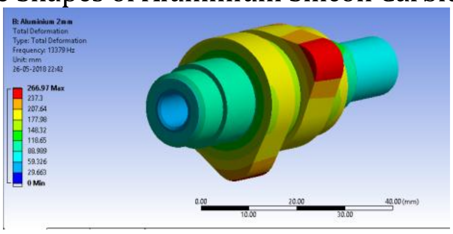


Mode Shape 2

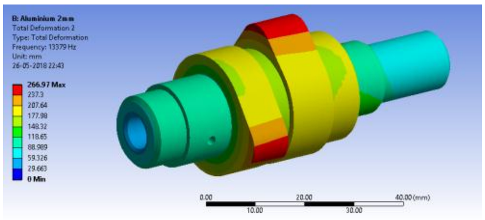


Mode Shape 3

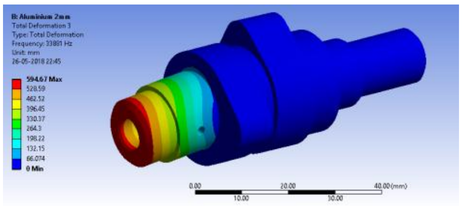
2. Mode Shapes of Aluminium Silicon Carbide



Mode Shape 1

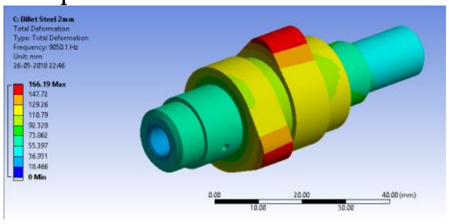


Mode Shape 2

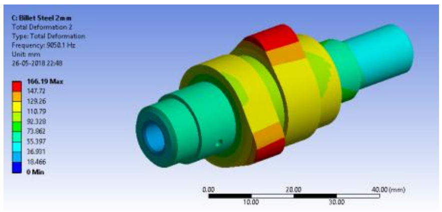


Mode Shape 3

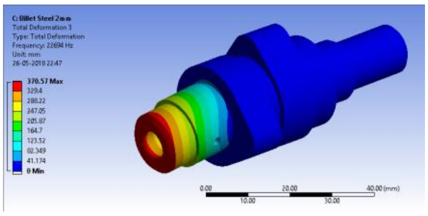
3. Mode Shape of Billet Steel



Mode Shape 1



Mode Shape 2



Mode Shape 3

Material	Mode Shapes	Frequency
Chilled Cast Iron	1	9400
	2	23572
	3	23869
Aluminium Silicon Carbide	1	13379
	2	33881
	3	34320
Billet Steel	1	9050
	2	22694
	3	22980

Table – Mode Shape Frequencies

V. RESULTS AND CONCLUSION

1. Static Analysis Results

Thus effective results are interpreted from the static analysis as discussed from previous sections. When the camshaft subjected to static loading condition it exhibits internal stresses on the Camshaft. While doing static analysis the load is applied at cam lobe location and other two ends are constrained to satisfy degrees of freedom. As a result, it induces equivalent stress distribution over the camshaft and tends to material deformation. The static results of all the different materials considered which are considered for the material optimization of the camshaft and checked for the better material to replace the existing camshaft.

	Chilled Cast Iron	Aluminium Silicon Carbide	Billet Steel
Von Misses Stresses	26	25	25
	0.05	0.04	0.04
Deformation	$9.5*10^{-3}$	$1.1*10^{-3}$	$9.3*10^{-3}$
	0	0	0

From the above Table, it can also be observed that by comparing the stress and the deformation valves obtained from the analysis, the Billet Steel and the Aluminium Silicon Carbide also has the equal opportunity to be considered for manufacturing the camshaft, as we know that the camshaft are high precision part similar care must be taken while manufacturing the Camshaft with the other two materials and can be considered for the real world usage, as we know the techonolgy is improving day by day new methods and new materials must be considered and tried with the existing camshaft and can be used for its better and improved performance and life of the Camshaft.

2. Modal Analysis-

Material	Mode Shapes	Frequency
Chilled Cast Iron	1	9400
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	2	33881
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Billet Steel	1	9050
	2	22694
	3	22980

The results obtained from analysis explains, initial 3 mode shapes are considered; while remaining 3modes are being not considered, but listed in above Table. It is observed that obtained mode shapes indicated behaviour of camshaft subjected to bending and twisting phenomenon It helps to identify the critical modes which causes failure of Camshaft. Thus, it is concluded that higher the excitation leads to variation of frequencies and mode shapes respectively.

VI. Conclusion

The main objective of this thesis is to perform structural analysis that has been studied in this part of research. The linear static analysis is performed and various stresses and deformation of the Camshaft is observed. Regarding to modal analysis, the dynamic behavior of the camshaft is studied under specified boundary condition. However, the research on stress analysis and modal analysis had been carried out on Camshaft; there is a limited research on various dynamic conditions as the camshaft has very varying characteristics inside the engine, the camshaft undergoes varying loads depending on the acceleration, as the acceleration is independent on each different user of an automobile. In this study, the Camshaft of two-wheeler automobile engine is used as it most important part of an automobile engine as it is called as brain of an engine, where it stimulates each function of all the 4strokes inside the engines, which is directly proportional to the entire performance of an engine.

VII. References

[1] R.D. Nipane, R.K. Patil, (2015) Modelling and Fatigue analysis of Metal Matrix Composite Camshaft using Finite Element Analysis, International Engineering Research Journal (IERJ) Volume 1, SavitribaiPhule Pune University, Wagholi, Pune India.

[2] B. VijayaRamnath, C. Elanchezhian, RM. Annamalai, S. Aravind, T. Sri Ananda Atreya1, V. Vignesh and C. Subramanian, (2013) Aluminium Metal Matrix Composites, Adv.Master. Sci (38).

[3] Anthony Macke B.F. Schultz, PradeepRohatgi, FASM. (2012) Offer the Automotive Industry an Opportunity to Reduce Vehicle Weight, Improve Performance, UMW Centres for Composite Materials and Advanced Materials Manufacture, University of Wisconsin–Milwaukee.

[4] C. Baron, H. Springer (2017), "Properties of particle phases for metal-matrix-composite design", Metal-Matrix-Composite Design.*

[5] I. Ucun, H. Bayrakceken, S. Tasgetiren (2006), Fracture Analysis of Camshaft made from Nodular cast iron, Engineering Failure Analysis (2006), AfyonKocatepe University, Mechanical Education Department, Technical Education Faculty, Afyon Turkey.

[6] Zeyaullah Ansari, Mohd Anwar, MdYousuf Ahmed (2017). Finite Element Analysis of Automobile Camshaft, International Journal for Research in Applied Science & Engineering Technology (IJRASET).

[7] PetrHejma, Martin Svoboda, Jan Kampo, Josef Soukup (2016), Analytic analysis of a cam mechanism, XXI

International Polish–Slovak Conference "Machine Modeling and Simulations 2016".

[8] Uma Mahesh, Bhaskar Reddy, Jaya Kishore (2015), Computational Geometric Modelling and Finite Element Structural Analysis of Automobile Camshaft, International Journal of Emerging Technology and Advanced Engineering.

[9] S.T Mavhungu, E T Akinlabi, M.A Onitiri, F.M Varachia (2017) Aluminium Matrix Composite for Industrial Use: Advances and Trends, International Conference on Sustainable Materials Processing and Manufacturing, SMPM 2017, January 2017, Kruger National Park.

[10] J. Michalski, J. Marszalek, K. Kubiak (2000) An experimental study of diesel engine cam and follower wear with particular reference to the properties of the materials, Faculty of Mechanic Engineering and Aeronautics, Rzeszo´w Uniİersity of Technology, 35-959 Rzeszo´w, ul. W. Pola 2, Poland.

[11] Rudragouda R patil, Santosh S Ghorpade, R Harish, V Santosh Kumar (2017) Contact analysi of a Cam and Follower in Two Wheeler, International Journal of engineering Technology Science and Research.

[12] Samata Jain, Vikas Bansal (2016) Static structural and Modal Analysis of Engine Camshaft using ANSYS Software, International Journal of Engineering Technology, Management and Applied Science.