A Comparative Study of Static and Dynamic Analysis of Automobile Camshaft Made of Different Materials

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Abstract : ***Camshafts used in the engines provide the required motion for the inlet and exhaust valves. These mechanical components convert the rotary motion into the linear motion and vice versa. In the present work, the main objective is to evaluate the dynamic response of the camshaft of an automobile made by different materials. To meet the higher target of power, cam shaft have to run at higher speeds. Because of this reason the cam shaft will be subjected to torsional vibrations due to gyroscopic effect and centrifugal force of the rotating elements mounted along with the shaft. Thus an analysis has been performed to find the deflections and stresses at the resonance frequencies of various materials like Aluminum-silicon carbide (Al-SiC), AISI 1065 Carbon steel, spheroid graphite cast iron, chilled cast iron and forged steel. An angular velocity of 785 rad/sec is given about the shaft axial direction. Both end of the camshaft is fixed in all Degrees of freedom except rotation. Finally, the results obtained for different materials are compared to find out the best material among them as the camshaft.***

IndexTerms –Camshaft, Al-SiC, AISI 1065 Carbon steel, spheroid graphite cast iron, chilled cast iron and forged steel structural analysis, modal analysis, harmonic analysis.

I. INTRODUCTION

A camshaft is a shaft to which a cam is affixed or of which a cam forms an integral part. The prime function of the camshaft is to operate the fuel injectors and poppet valves in the engine which takes the rotary motion of the engine and translates it into the reciprocating motion necessary to operate the intake and exhaust valves of the cylinders [1-2]. The cams have been attached to camshaft with protruding oblong lobes, one for each valve. The lobes exert pressure on the valves, or a transition mechanism that forces them to open as they rotate. The intake valve begins its process of opening from the lobe when the piston begins its downward combustion stroke. This rising piston force forces the gases out, and when the piston reaches the top of its cycle, the valve closes [3].

Vinayaka Bongale and Dr. N Kapilan[4] explained that while rotating, these masses create centrifugal forces and if the mass position is eccentric, then there is possibility for imbalance in the system. Certain times, this imbalance due to vibration is the main cause of bearing wear out and failure of the shaft. F.S. Silva [4] has done analysis on damaged crank shafts. After relieving the stresses again the same crank shafts worked for some more time. The invisible cracks and sharp edges are the potential sources of wear out the journals. Also he discussed about major failure modes of the cam shafts. It is also found that even misalignment in the shaft system, fatigue loading, improper loading, improper distribution of load, improper material selection, temperature range are also possible causes of failure. Zhi-Wei yu A Xiao-lei Xu [4] has done experimentation to find the cause of failure of the cam shafts. He observed that most of the failures are happening at the key ways. This can be attributed to stress concentration effect along with stress corrosion. The tests show that the failure mode is fatigue fracture. Even material forming techniques also are potential sources of failure of the cams.

Camshaft material is the most important factor which influence the performance i.e. bearing wear [4], residualstress [4], and keyways [4]. The materials used for the camshaft depends on the quality and type of engine being manufactured [6]. To fulfill modern advancement i.e. higher strength to weight ratio composite like Al- SiC[5] is also used which is not only stiffer but also provide good strength and reliability. M.Shobha[6] found that the camshaft material can be replaced with steel and aluminum alloy. Neeraj Sarswat et. al. [7] concluded that decrement in element sizes increases the number of nodes and elements, and makes the meshing fine.

In the present work, the camshaft has been designed in NX-7.5 CAD and imported into ANSYS. Static, modal and harmonic analyses were carried to calculate the total deflections, Von Misses stress, natural frequencies, mode shapes, maximum stress and peak amplitudes of various materials.

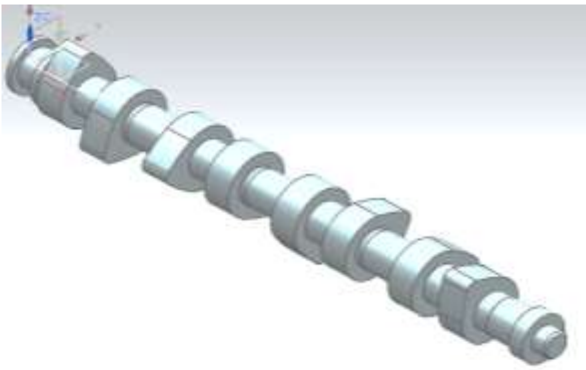


Fig.1: The 3D model of the cam shaft

II. Materials and Modeling

The model of the camshaft required is designed in NX-7.5 CAD and imported into ANSYS to perform the finite element analysis. The tedious work of formulating and assembling of matrices are done by the software and finally displacements and stress values are given as output. The modal analysis of the cam shaft is performed using finite element analysis to find the natural frequencies. The harmonic analysis was conducted to know the peak amplitudes at the resonance points. The process is repeated for different materials.

The materials chosen for camshaft are:

1. Aluminum silicon carbide (63%Al 37%SiC)
2. AISI 1065 carbon steel (98%Fe 0.60%Mn 0.60%C 0.05% S 0.04%P)
3. Spheroidal graphite cast iron(3.2%C 2.2%Si 0.2%Mn 0.03%Mg 0.005%P 0.002%S 0.40%Cu)
4. Chilled cast iron or white cast iron(4%C, 0.7%Si, 0.6%Mn)
5. Forged steel.

III. Structural Analysis

The boundary conditions followed during analysis are as follows.

1. One end of the shaft is fixed in all Degrees of freedom except rotations.
2. An angular velocity of 785 rad/sec is given about the shaft axial.

The total deflection and Von Misses stresses are calculated for selected materials and are shown in Fig 2-6

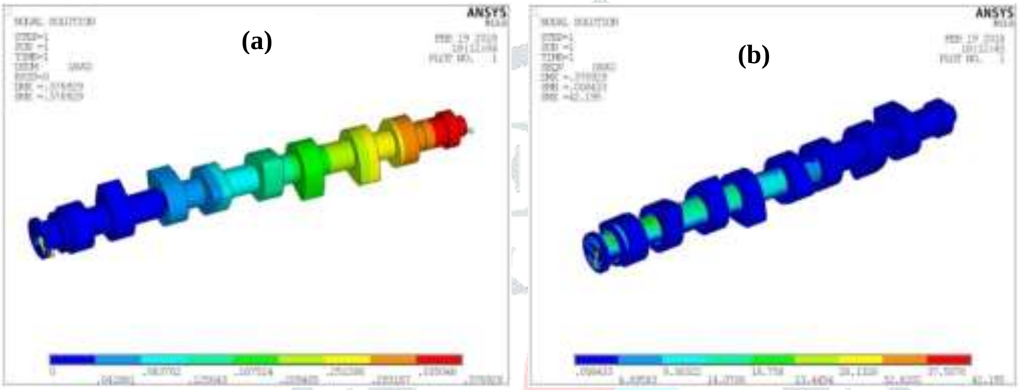


Fig.2:(a) Total deflection (b) Von Misses stress for Al-SiC

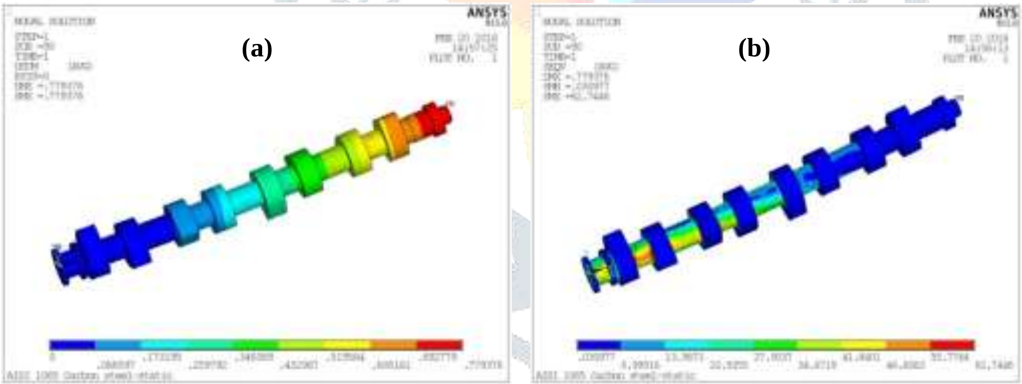


Fig.3:(a) Total deflection (b) Von Misses stress for AISI 1065 carbon

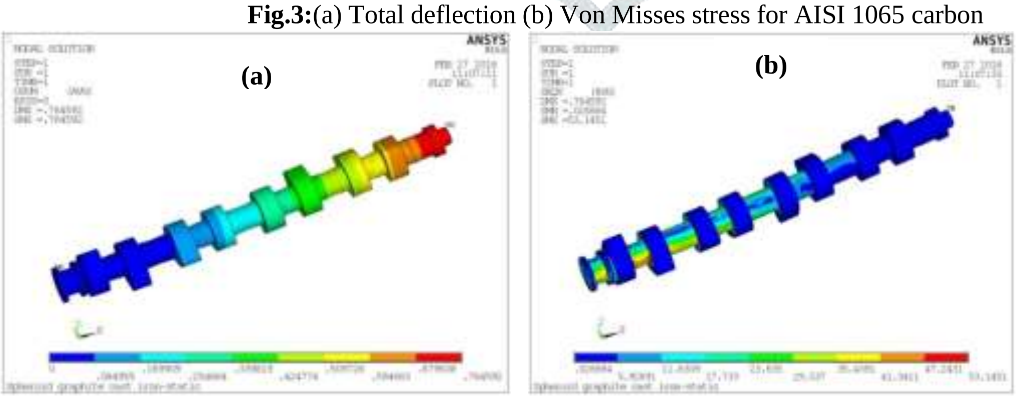


Fig.4:(a) Total deflection (b) Von Misses stress for Spheroidal graphite Cast Iron

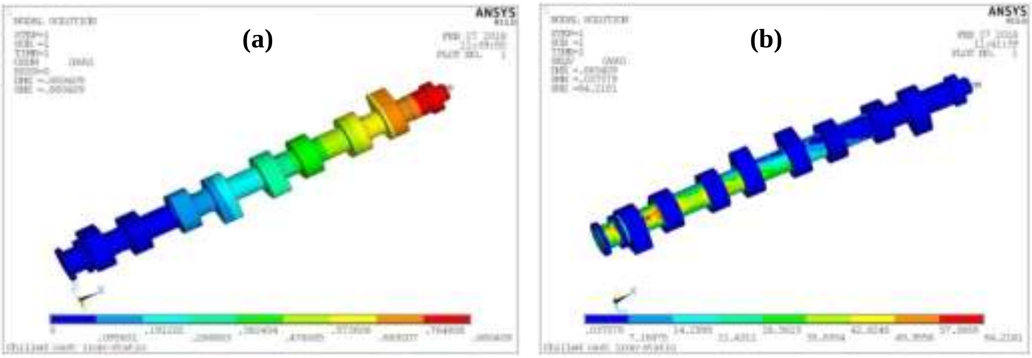


Fig.5:(a) Total deflection (b) Von Misses stress for Chilled Cast Iron

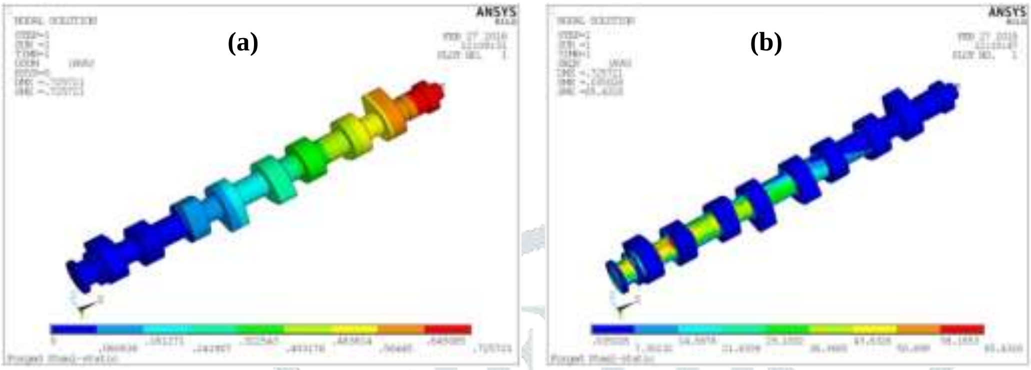
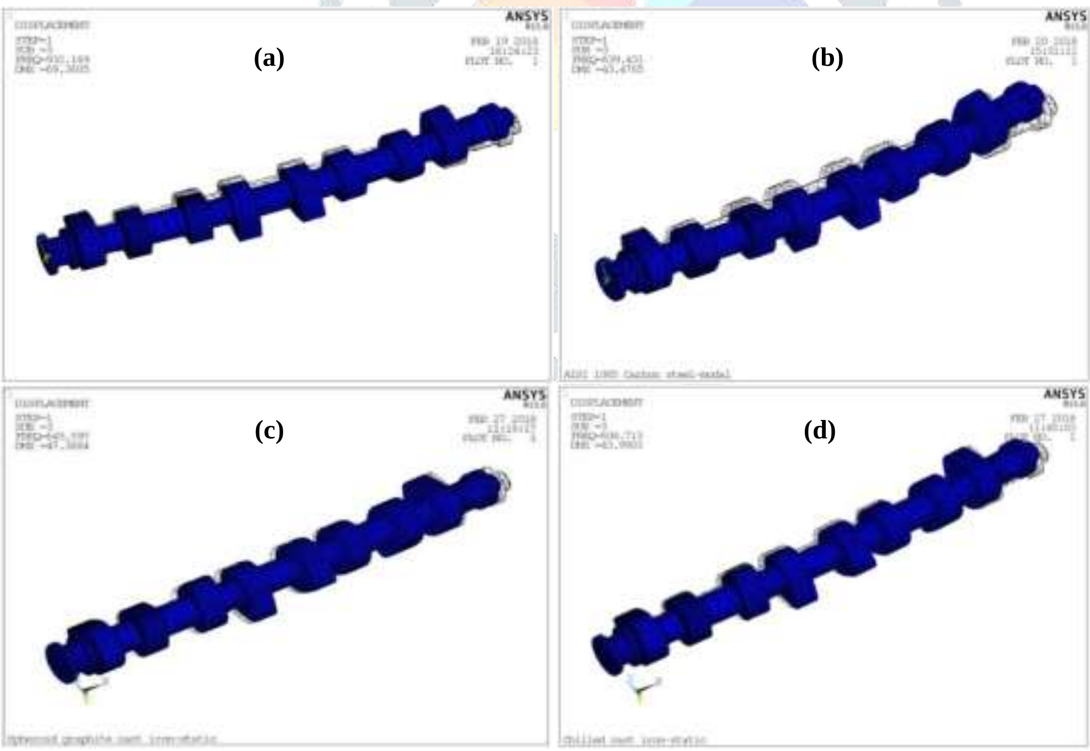


Fig.6:(a) Total deflection (b) Von Misses stress for Forged Steel

IV. Modal Analysis

Modal analysis is conducted on cam shaft to know the different natural frequencies and mode shapes acting upon on the cam shaft. To do modal analysis only boundary conditions are used and no external loading. From the modal analysis, the first 10 natural frequencies for different materials are observed exemplified in Table and mode shape of materials is shown in Fig 7.



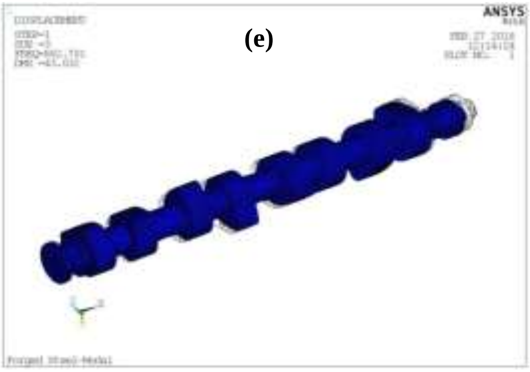


Fig 7: Mode shape @ frequency (a) 932.16 Hz for Al-SiC material (b)639.4 Hz for AISI 1065 Carbon Steel material (c) 645.5 Hz for Spheroid Graphite Cast Iron material (d) 608.7 Hz for Chilled Cast Iron material (e) 662.7 Hz for Forged Steel material

V. HARMONIC ANALYSIS

The Harmonic analysis gives the ability to predict the sustained dynamic behavior of the structures and to know the maximum stress and peak amplitudes of the frequency, thus enabling to verify whether or not the designs will successfully overcome resonance, fatigue, and other harmful effects of forced vibrations. The boundary conditions applied are same as static analysis but the applied load is considered as sinusoidal load when a harmonic analysis is done. Frequency Vs Von Misses stresses are shown in Fig 8.

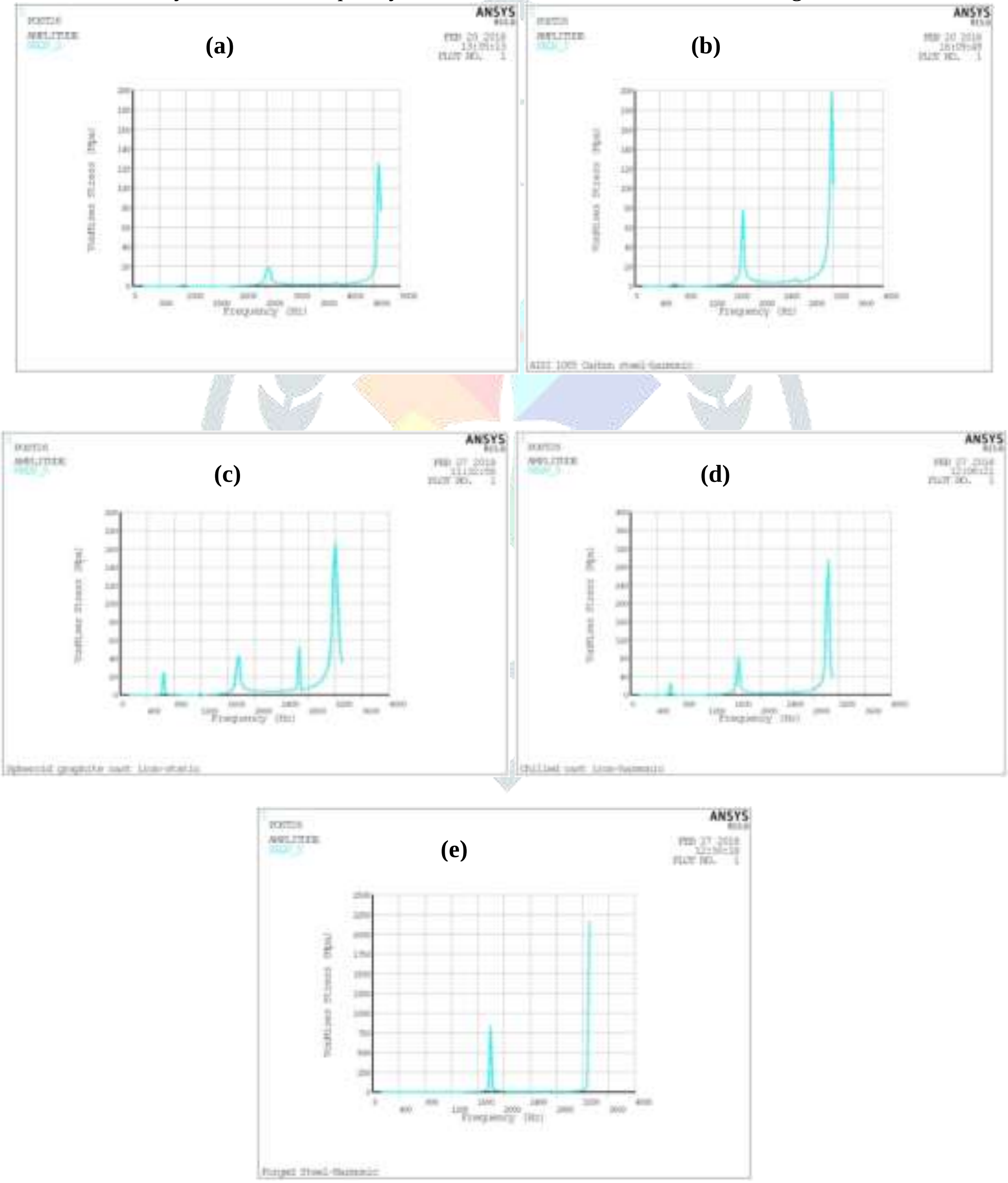


Fig 8: Frequency Vs Von Misses stress for harmonic analysis of (a)Al-SiC (b) AISI 1065 Carbon Steel material (c) Spheroid Graphite Cast Iron material (d) Chilled Cast Iron material (e) Forged Steel material.

VI. RESULTS AND DISCUSSION

Structural Analysis of Camshaft					
	Al-SiC	AISI 1065 Cast Iron	Spheroid Graphite Cast Iron	Chilled Cast Iron	Forged Steel
Total deflection (mm)	0.37	0.77	0.764	0.86	0.725
Von Misses Stress(N/mm^2)	42.19	62.7	53.14	64.2	65.43
Weight (KG)	1.1	2.8	2.36	2.73	2.86
Factor of safety (Yield strength/Von Misses stress)	140/42 =3.33	490/62.7 =7.81	345/53.14 =6.49	276/64.2 =4.29	625/65.4 =9.55
Modal Analysis of Camshaft					
Mode. No	**Frequency (Hz)**				
1	154	106.02	107.03	100.84	109.84
2	154.67	106.1	107.11	100.9	109.91
3	932.17	639.43	645.6	608.71	662.7
4	932.35	639.56	645.71	608.78	662.8
5	1709.1	1172.4	1189.7	1161.6	1236.6
6	2521.6	1729.7	1746.7	1648.9	1793.8
7	2527.5	1733.8	1750.7	1652.2	1797.7
8	3841.5	2635.1	2661.2	2513	2733.4
9	4609.7	3162.1	3194.1	3020.8	3282.6
10	4638.2	3181.6	3213.3	3035.9	3300.9

In the Static analysis, total deflection, Von Misses stress and weight are found minimum for the Aluminum-silicon carbide (Al-SiC) material; however the Factor of safety is lower for this material (Al-SiC), as compared to other materials. From the Modal analysis, it is found that natural frequency is high for Aluminum-silicon carbide (Al-SiC) material. From the Harmonic analysis, the maximum peak amplitude occurs at frequency 4638.2 Hz i.e. resonance occurs at this frequency. From these analyses it is concluded that Aluminum-silicon carbide (Al-SiC) material is the best material as compared to other materials for manufacturing of camshaft to meet higher target of power.

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