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Paper Authors

*** P.SRIKANTH, R.RAMBABU, K.L.N.MURTHY.**

* Eswar College of Engineering.

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FRACTURE, FATIUGE GROWTH RATE AND VIBRATION ANALYSIS OF CAM SHAFTS USED IN RAILWAYS

[1]P.SRIKANTH, [2]R.RAMBABU, [3]K.L.N.MURTHY
[1]PG Scholar, Eswar College of Engineering, Narasaraopet, Andhra Pradesh.
[2]Assistant Professor, Eswar College of Engineering, Narasaraopet, Andhra Pradesh.
[3]Assistant Professor, Eswar College of Engineering, Narasaraopet, Andhra Pradesh.
pulisrikanth.iiit@gmail.com rambaburajavarapu@gmail.com Kandunuri.123@gmail.com

ABSTRACT:
The cam shaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. It consists of a cylindrical rod running over the length of the cylinder bank with a number of oblong lobes protruding from it, one for each valve. The cam lobes force the valves open by pressing on the valve, or on some intermediate mechanism as they rotate. This shaft also provides the drive to the ignition system.

The camshaft is driven by the crankshaft through timing gears cams are made as integral parts of the camshaft and are designed in such a way to open and close the valves at the correct timing and to keep them open for the necessary duration. A common example is the camshaft of an automobile, which takes the rotary motion of the engine and translates it in to the reciprocating motion necessary to operate the intake and exhaust valves of the cylinders.

In this work, a camshaft is designed for multi cylinder engine and 3D-model of the camshaft is created using modeling software pro/Engineer. The modeled in creo is imported in to ANSYS. After completing the element properties, meshing and constraints the loads are applied on camshaft for three different materials namely aluminium alloy, forged steel and cast iron to determine the displacement, equivalent stress of the cam shaft. After taking the results of static analysis, the model analysis and harmonic analysis are done one by one.

INTRODUCTION

A **cam** is a rotating or sliding piece in a mechanical linkage used especially in transforming rotary motion into linear motion or vice versa. It is often a part of a rotating wheel (e.g. an eccentric wheel) or shaft (e.g. a cylinder with an irregular shape) that strikes a lever at one or more points on its circular path. The cam can be a simple tooth, as is used to deliver pulses of power to a steam hammer, for example, or an eccentric disc or other shape that produces a smooth reciprocating (back and forth) motion in the *follower*, which is a lever making contact with the cam.

OVERVIEW

The cam can be seen as a device that translates from circular to reciprocating (or sometimes oscillating) motion. A common example is the camshaft of an automobile, 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.

The opposite operation, translation of reciprocating motion to circular motion, is done by a crank. An example is the crankshaft of a car, which takes the reciprocating motion of the pistons and translates it into the rotary motion necessary to operate the wheels.

Cams can also be viewed as information-storing and -transmitting devices. Examples are the cam-drums that direct the notes of a music box or the movements of a screw machine's various tools and chucks. The information stored and transmitted by the cam is the answer to the question, "What actions should happen, and when?" (Even an automotive camshaft essentially answers that question, although the music box cam is a still-better example in illustrating this concept.)

Certain cams can be characterized by their displacement diagrams, which reflect the changing position a roller follower would make as the cam rotates about an axis. These diagrams relate angular position to the radial displacement experienced at that position. Several key terms are relevant in such a construction of plate cams: base circle, prime circle (with radius equal to the sum of the follower radius and the base circle radius), pitch curve which is the radial curve traced out by applying the radial displacements away from the prime circle across all angles, and the lobe separation angle (LSA - the angle between two adjacent intake and exhaust cam lobes). Displacement diagrams are traditionally presented as graphs with non-negative values. A **camshaft** is a shaft to which a cam is fastened or of which a cam forms an integral part.

LITERATURE SURVEY

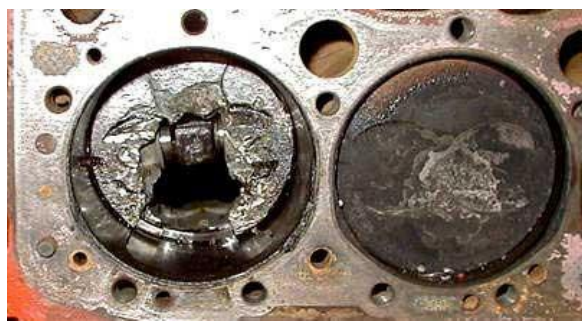
CAMSHAFT CONFIGURATION

Single Overhead Cam

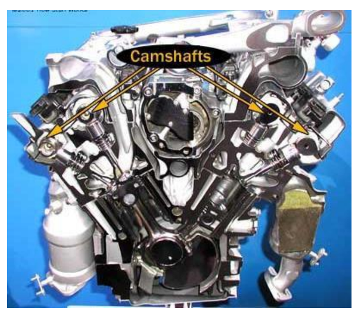
This arrangement denotes an engine with **one cam per head**. So if it is an inline 4-cylinder or inline 6-cylinder engine, it will have one cam; if it is a V-6 or V-8, it will have two cams (one for each head).

The cam actuates rocker arms that press down on the valves, opening them. **Springs** return the valves to their closed position. These springs have to be very strong because at high engine speeds, the valves are pushed down very quickly, and it is the springs that keep the valves in contact with the rocker arms. If the springs were not strong enough, the valves might come away from the rocker arms and snap back. This is an undesirable situation that would result in extra wear on the cams and rocker arms.

On single and double overhead cam engines, the cams are driven by the crankshaft, via either a belt or chain called the **timing belt** or **timing chain**. These belts and chains need to be replaced or adjusted at regular intervals. If a timing belt breaks, the cam will stop spinning and the piston could hit the open valves.



Double Overhead Cam



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A double overhead cam engine has **two cams per head**. So inline engines have two cams, and V engines have four. Usually, double overhead cams are used on engines with four or more valves per cylinder -- a single camshaft simply cannot fit enough cam lobes to actuate all of those valves.

The main reason to use double overhead cams is to allow for more intake and exhaust valves. More valves means that intake and exhaust gases can flow more freely because there are more openings for them to flow through. This increases the power of the engine.

The final configuration we'll go into in this article is the pushrod engine.

Pushrod Engines

Like SOHC and DOHC engines, the valves in a pushrod engine are located in the head, above the cylinder. The key difference is that **the camshaft on a pushrod engine is inside the engine block**, rather than in the head.

The cam actuates long rods that go up through the block and into the head to move the rockers. These long rods add mass to the system, which increases the load on the valve springs. This can limit the speed of pushrod engines; the overhead camshaft, which eliminates the pushrod from the system, is one of the engine technologies that made higher engine speeds possible. The camshaft in a pushrod engine is often driven by gears or a short chain. Gear-drives are generally less prone to breakage than belt drives, which are often found in overhead cam engines.

DESIGN CALCULATIONS

PRESSURE CALCULATIONS

Bore $\times$ $stroke(mm) = 57 \times 58.6$
Displacement =149.5CC
Maximum power = 13.8bhp @8500rpm
Maximum torque = 13.4Nm @ 6000 rpm
Compression ratio =9.35/1
Density of petrol $C_8H_{18} = 737.22 \frac{kg}{m^3} at\ 60F$
= 0.00073722 kg/cm^3
= 0.00000073722 kg/mm^3
T = 60F =288.855K =15.55^{0}C
Mass = density $\times$ $volume$
m = 0.00000073722$\times$ 149500
m = 0.11kg
Molecular cut for petrol 144.2285 g/mole
PV = mRT
$P = \frac{mRT}{V} = \frac{0.11 \times 8.3143 \times 288.555}{0.11422 \times 0.0001495} = \frac{263.9}{0.00001707}$
P = 15454538.533 j/m^3 = n/m^2
P =15.454 N/mm^2

DESIGN OF CAMSHAFT

The cam is forged as one piece with the camshaft
The diameter of camshaft
D^1 = 0.16$\times$cylinder bore+12.7D^1 = 0.16 $\times$ 57+12.7=21.82mm
The base circle diameter is about 4mm greater than camshaft diameter
Base circle diameter = 21.82+3 = 24.82mm = 25mm
Width of camshaft
w^1 = 0.09$\times$cylinder bore+6
W^1 = 0.09$\times$57+6 = 11.13mm
OA = minimum radius of camshaft + (1/2$\times$ diameter of roller)

= 12.5+ (1/2$\times$41) = 33mm

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MATERIALS

- **Forged steel**
- **Cast iron**
- **Aluminum alloy**

INTRODUCTION TO CAD

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

Its use in designing electronic systems is known as electronic design automation, or EDA. In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

INTRODUCTION TO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

The name was changed in 2010 from Pro/ENGINEER Wildfire to CREO. It was announced by the company who developed it, Parametric Technology Company (PTC), during the launch of its suite of design products that includes applications such as assembly modeling, 2D orthographic views for technical drawing, finite element analysis and more.

PTC CREO says it can offer a more efficient design experience than other modeling software because of its unique features including the integration of parametric and direct modeling in one platform. The complete suite of applications spans the spectrum of product development, giving designers options to use in each step of the process. The software also has a more user friendly interface that provides a better experience for designers. It also has collaborative capacities that make it easy to share designs and make changes.

PTC also offers comprehensive training on how to use the software. This can save businesses by eliminating the need to hire new employees. Their training program is available online and in-person, but materials are available to access anytime.

A unique feature is that the software is available in 10 languages. PTC knows they have people from all over the world using their

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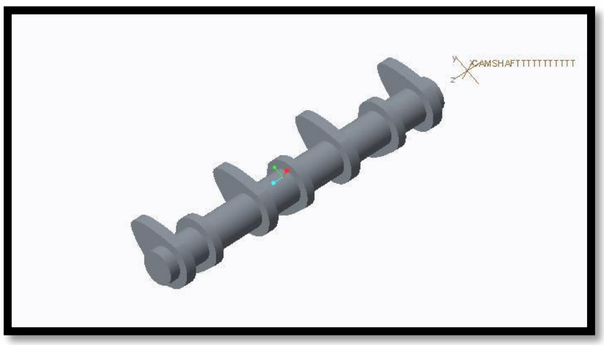
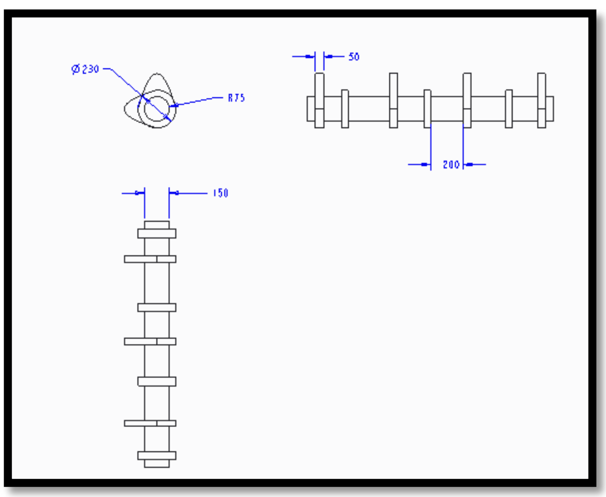
software, so they offer it in multiple languages so nearly anyone who wants to use it is able to do so.

3D MODEL OFCAM SHAFT



2D MODEL



INTRODUCTION TO FEA

Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

One of the first applications of FEA was, indeed, to find the stresses and strains in engineering components under load. FEA, when applied to any realistic model of an engineering component, requires an enormous amount of computation and the development of the method has depended on the availability of suitable digital computers for it to run on. The method is now applied to problems involving a wide range of phenomena, including vibrations, heat conduction, fluid mechanics and electrostatics, and a wide range of material properties, such as linear-elastic (Hookean) behavior and behavior involving deviation from Hooke's law (for example, plasticity or rubber-elasticity).

INTRODUCTION TO ANSYS

Structural Analysis

ANSYS Autodyn is computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions.

ANSYS Mechanical

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal–structural and thermo-electric analysis.

FLUID FLOW

The ANSYS/FLOTRAN CFD (Computational Fluid Dynamics) offers comprehensive equipment for studying -dimensional and 3-

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dimensional fluid go with the flow fields. ANSYS is able to modeling a sizable variety of analysis sorts such as: airfoils for pressure analysis of plane wings (elevate and drag), drift in supersonic nozzles, and complicated, three-dimensional waft styles in a pipe bend. In addition, ANSYS/FLOTRAN may be used to carry out obligations together with:

•Calculating the gasoline pressure and temperature distributions in an engine exhaust manifold

•Studying the thermal stratification and breakup in piping systems

•Using drift blending research to evaluate ability for thermal surprise

•Doing herbal convection analyses to evaluate the thermal performance of chips in digital enclosures

•Conducting warmness exchanger research related to exceptional fluids separated by using strong regions

INTRODUCTION TO CFD

Computational fluid dynamics, commonly abbreviated as CFD, is a department of fluid mechanics that makes use of numerical strategies and algorithms to clear up and analyze problems that involve fluid flows. Computers are used to carry out the calculations required to simulate the interplay of beverages and gases with surfaces described by boundary conditions. With high-pace supercomputers, higher solutions can be performed. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios together with transonic or turbulent flows. Initial experimental validation of such software program is executed using a wind tunnel with the very last validation coming in complete-scale testing, e.g. Flight assessments.

STATIC ANALYSIS OF CAM SHAFT MATERIALS - FORGED STEEL

Young's modulus = 205000mpa

Poisson's ratio = 0.3

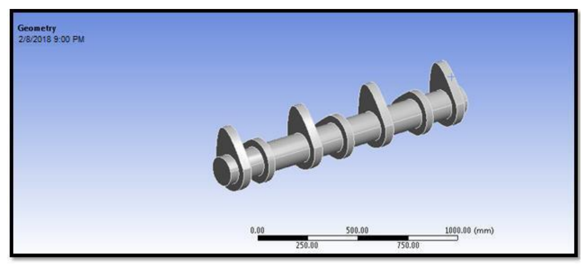
Density = 7850kg/mm^3

Save creo Model as .iges format

→→Ansys → Workbench→ Select analysis system → static structural → double click →→Select geometry → right click → import geometry → select browse →open part → ok →→ Select mesh on work bench → right click →edit

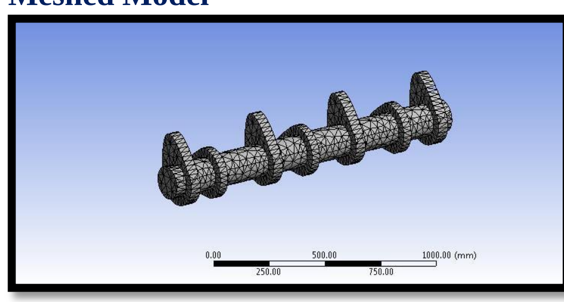
Double click on geometry → select MSBR → edit material →

Imported Model from CREO

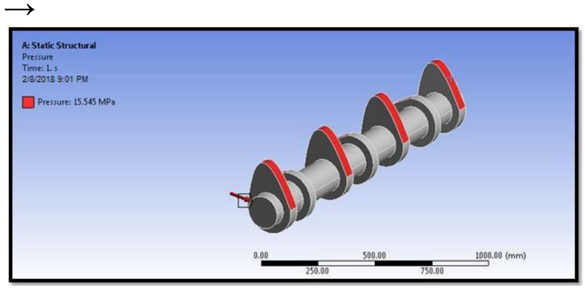


Select mesh on left side part tree → right click → generate mesh →

Meshed Model

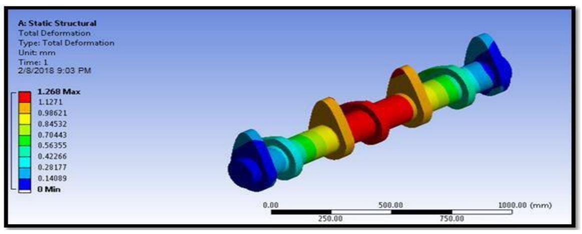


Select static structural right click → insert → select rotational velocity and fixed support → Select displacement → select required area → click on apply → put X,Y,Z component zero →

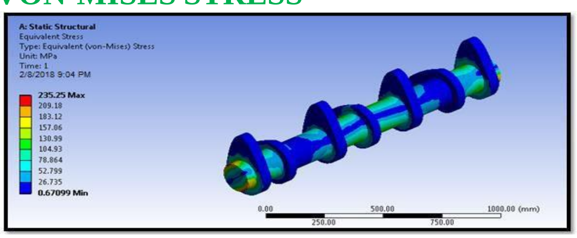


Select force → select required area → click on apply → enter rotational velocity
Select solution right click → solve →
Solution right click → insert → deformation → total → Solution right click → insert → strain → equivalent (von-mises) →
Solution right click → insert → stress → equivalent (von-mises) →
Right click on deformation → evaluate all result

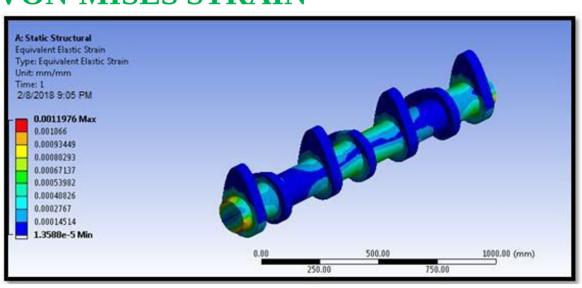
TOTAL DEFORMATION



VON-MISES STRESS

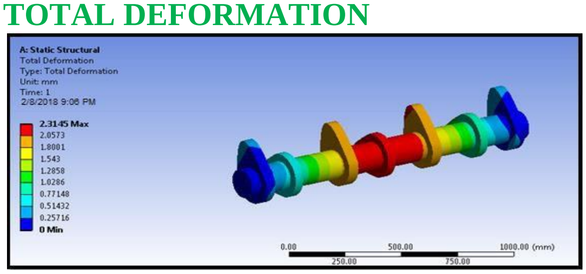


VON-MISES STRAIN

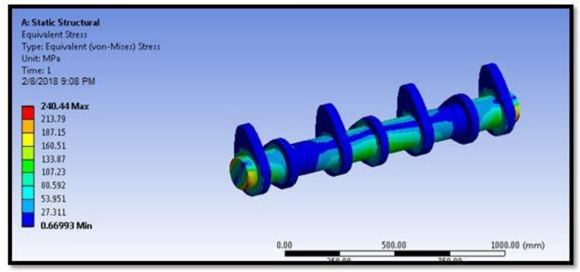


MATERIALS - CAST IRON

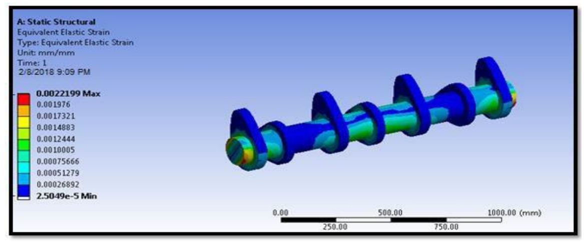
TOTAL DEFORMATION



VON-MISES STRESS

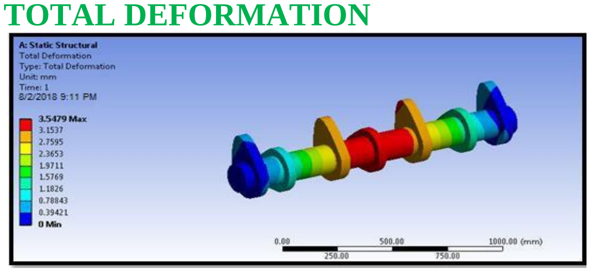


VON-MISES STRAIN

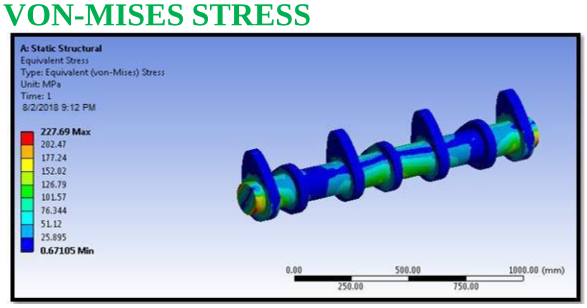


MATERIALS - ALUMINUM ALLOY

TOTAL DEFORMATION



VON-MISES STRESS



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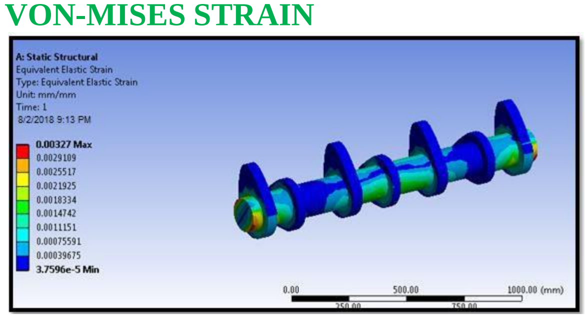

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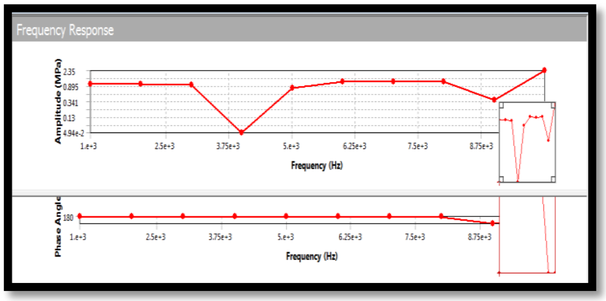
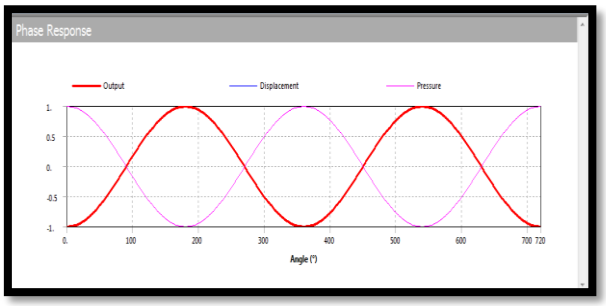
HARMONIC ANALYSIS OF CAMSHAFT

MATERIALS - FORGED STEEL

STRESS FREQUENCY RESPONSE

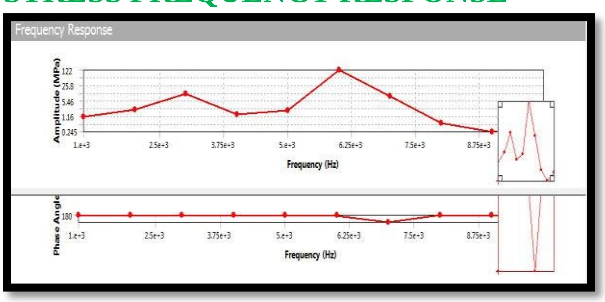


PHASE RESPONSE

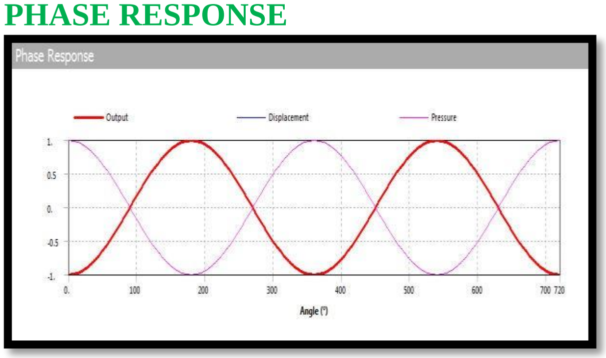


MATERIALS - CAST IRON

STRESS FREQUENCY RESPONSE

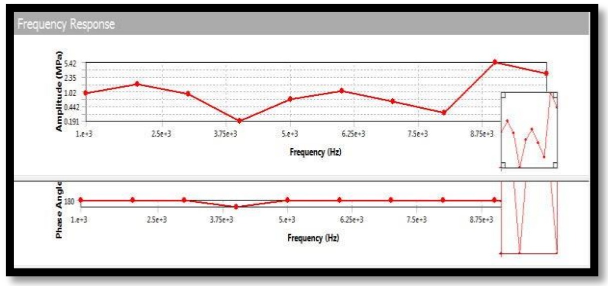


PHASE RESPONSE

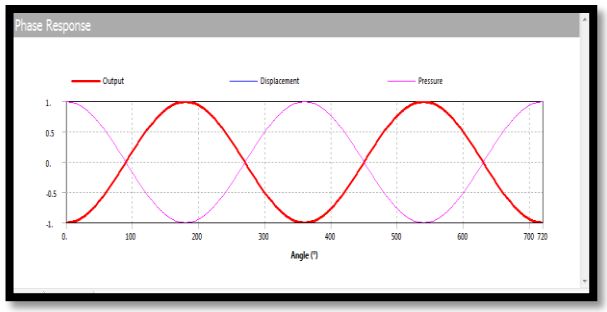


MATERIALS - ALUMINUM ALLOY

STRESS FREQUENCY RESPONSE

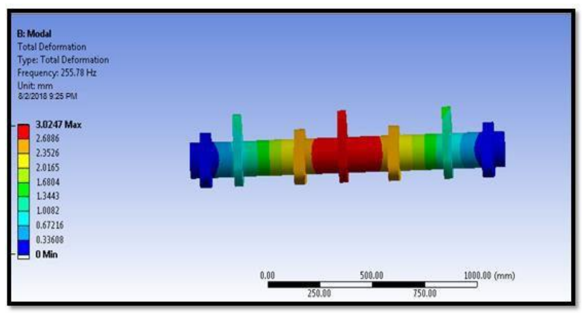


PHASE RESPONSE



MODAL ANALYSIS OF CAM SHAFT

TOTAL DEFORMATION 1



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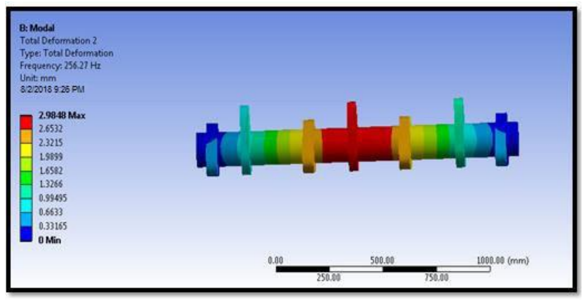

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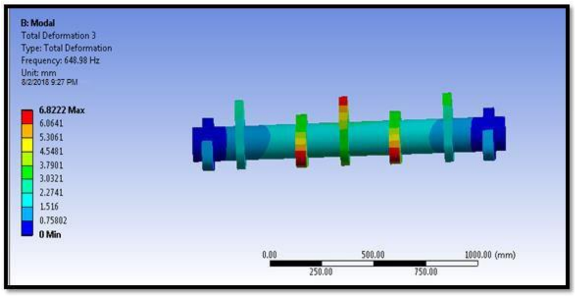
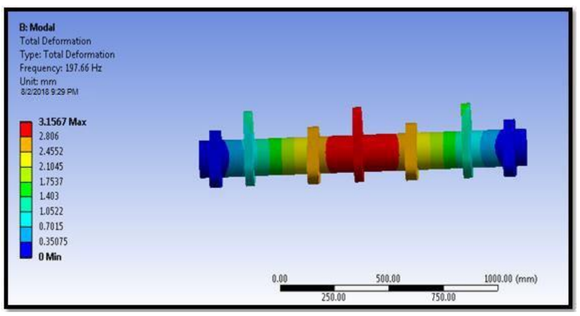
TOTAL DEFORMATION 3



MATERIALS - CAST IRON

TOTAL DEFORMATION 1



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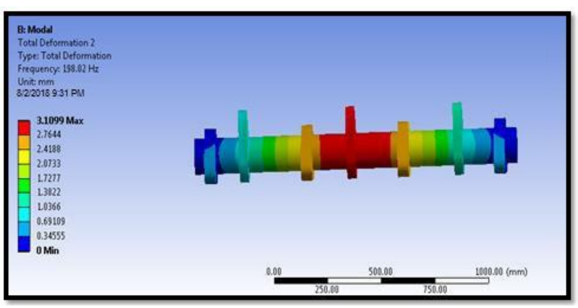

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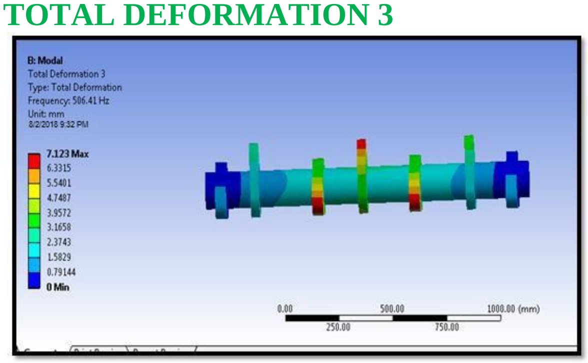
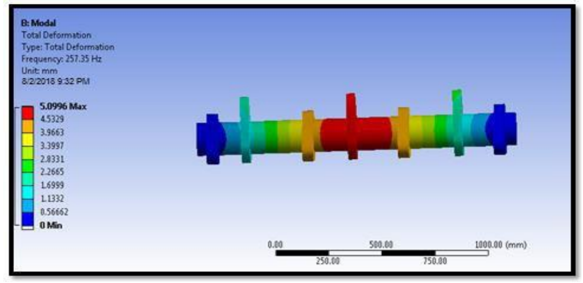


MATERIALS - ALUMINUM ALLOY

TOTAL DEFORMATION 1



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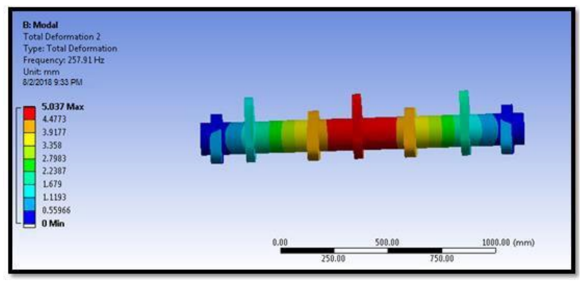

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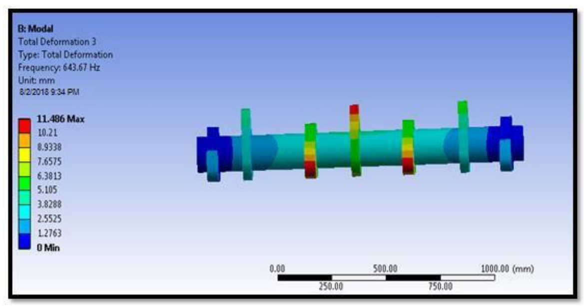

RESULTS TABLE

STATIC ANALYSIS RESULTS

Material	Deformation (mm)	Stress (N/mm^2)	Strain
Forged steel	1.268	235.25	0.0011976
Cast iron	2.3145	240.44	0.002219
Aluminum alloy	3.5479	227.69	0.00327

MODEL ANALYSIS RESULTS

Material	Deformation1 (mm)	Frequency (Hz)	Deformation 2 (mm)	Frequency (Hz)	Deformation 3 (mm)	Frequency (Hz)
Forged steel	3.0247	255.78	2.9848	256.27	6.8222	648.98
Cast iron	3.1567	197.66	3.1099	198.02	7.123	506.41
Aluminum alloy	5.0966	257.35	5.037	257.91	11.486	643.67

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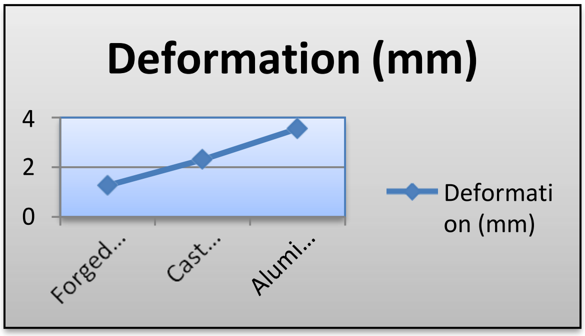
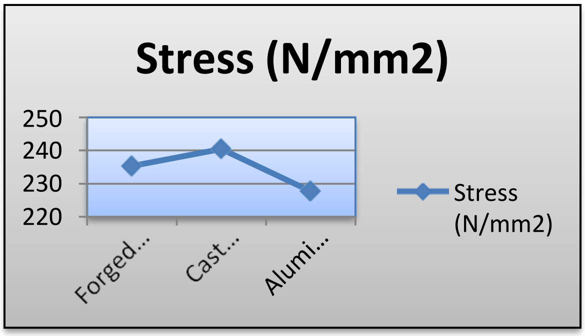
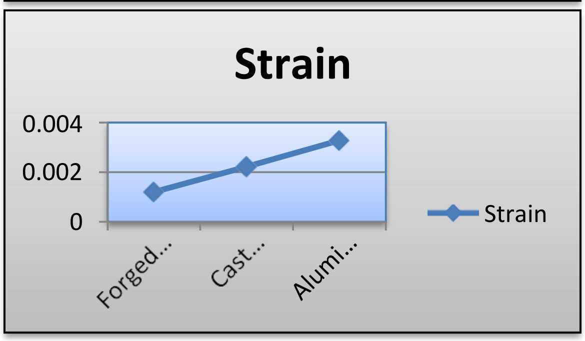
GRAPHS







CONCLUSION

The camshaft is driven by the crankshaft through timing gears cams are made as integral parts of the camshaft and are designed in such a way to open and close the valves at the correct timing and to keep them open for the necessary duration. A common example is the camshaft of an automobile, which takes the rotary motion of the engine and translates it in to the reciprocating motion necessary to operate the intake and exhaust valves of the cylinders.

By observing the static analysis the stress values are less for aluminum alloy compare with forged steel and cast iron.

By observing the modal analysis the deformation and frequency values are more for aluminum alloy.

So it can be conclude the aluminum alloy is better material for cam shaft

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