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Design and Analysis of Cam Shaft in Automobiles Using FEM

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ABSTRACT:

Camshaft is used in the engine for transfers' motion to inlet & exhaust valve. If transfer of motion is not proper then the strokes of the engine will not do in proper way. It also effects on performance of engine. To make work of camshaft in precise way, it is require in order designing a good mechanism linkage of camshaft. In four strokes engine one of the most important component is camshaft, such a important part and that over the years subject of extensive research. In this study, Design of Camshaft is done as per power stroke and suction stroke and its model is done in CATIA and Static and Model Analysis is carried in Ansys Work bench. By varying Materials like Cast Iron & Nickel chromium molybdenum steel and find out which is best material Suits for design.

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 it is used to deliver pulses of power to a steam hammer, for example, 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. 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. 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. A shaft with cam lobes(bumps) which is driven by gears, a belt, or a chain from the crankshaft. The lobes push on the valve lifters to cause the valves to open and close. The camshaft turns at half the speed of the crankshaft.

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CAMSHAFT BASICS:

The key parts of any camshaft are the lobes. As the camshaft spins, the lobes open and close the intake and exhaust valves in time with the motion of the piston. It turns out that there is a direct relationship between the shape of the cam lobes and the way the engine performs in different speed ranges. To understand why this is the case, imagine that we are running an engine extremely slowly at just 10 or 20 revolutions per minute (RPM) so that it takes the piston a couple of seconds to complete a cycle. It would be impossible to actually run a normal engine this slowly, but let's imagine that we could. At this slow speed we would use high slope cam lobes, shaped so that:

1. Just as the piston starts moving downward in the intake stroke (called top dead center, or TDC), the intake valve would open. The intake valve would close right as the piston bottoms out.
2. The exhaust valve would open right as the piston bottoms out (called bottom dead center, or BDC) at the end of the combustion stroke, and would close as the piston completes the exhaust stroke.

When you increase the RPM, the 10 to 20 RPM configuration for the camshaft does not work well. If the engine is running at 4,000 RPM, the valves are opening and closing 2,000 times every minute, or 33 times every second. At these speeds, the piston is moving very quickly, so the air/fuel mixture rushing into the cylinder is moving very quickly as well. When the intake valve opens and the piston starts its intake stroke, the air/fuel mixture in the intake runner starts to accelerate into the cylinder. By the time the piston reaches the bottom of its intake stroke, the air/fuel is moving at a pretty high speed. If we were to slam the intake valve shut, all of that air/fuel would come to a stop and not enter the cylinder. By leaving the intake valve open a little longer, the momentum of the fast-moving air/fuel continues to force air/fuel into the cylinder as the piston starts its compression stroke. So the faster the engine goes, the faster the air/fuel moves, and the longer we want the intake valve to stay open. We also want the valve to open wider at higher speeds this parameter, called valve lift, is governed by the cam lobe profile.

CAM TERMINOLOGY

Angle and Lift Terminology:

There are several terms and abbreviations which are used when discussing camshafts. The following abbreviations have to do with the location of the piston in the cycle.

TC or TDC, Top Center or Top Dead Center (piston at the highest point)

BC or BDC, Bottom Center (piston at lowest point)

BTC or BTDC, Before Top Center (piston rising)

ATC or ATDC, After Top Center (piston lowering)

BBC or BBDC, Before Bottom Center (piston lowering)

ABC or ABDC, After Bottom Center (piston risinng)

Some of the other terms used are illustrated in the drawing and are explained below.

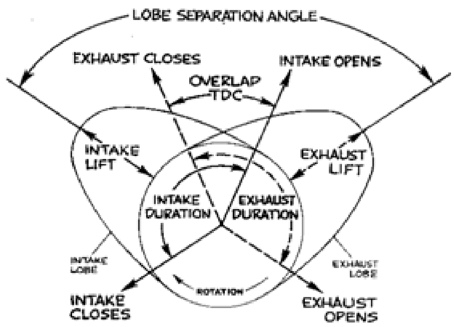

Fig 4.1 Cam Diagram

Valve Opening and Closing Angles, the angles (usually measured in crankshaft degrees) when the valves first leave and then return to their seats. The opening and closing angles may also refer to a specified nominal lift, e.g. at 0.050 in cam lift. For example, a cam's timing may be stated as 25-65-65-25. These numbers are (1) intake opening BTDC, intake closing ABDC, (3) exhaust opening BBDC and (4) exhaust closing ATDC. For these numbers to have meaning, the lift at which the numbers are taken must be specified.

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Lobe Terminology:

Some of the terminology, which describes a single lobe is illustrated in the drawing below.

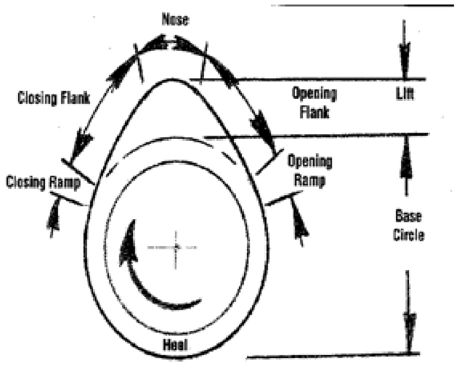

Fig 4.2 Lobe Diagram

Heel or Base Circle, the portion of the cam which is concentric with the bearings and has no lift.

Ramps, immediately adjacent to the base circle, the cam has a portion with low velocity so there is not a major collision as slack is removed from the valve train at the start of the lift event. Similarly, a closing ramp is used so the valve will seat gently and not bounce off the seat.

Flanks, the portion of the cam with large acceleration and velocity to get the valve moving as quickly as possible.

Nose or Toe, the portion of the cam with the smallest radius of curvature, opposite the heel. This part has the greatest lift.

Asymmetric Lobe, the opening and closing side of the cam are different.

Core, the rough part of the camshaft between the lobes, bearings and gears.

CAMSHAFT CONFIGURATION

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 arm that presses down 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 & can be 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. Damage from a piston striking a valve.

Fig 5.1.1 Damage from a piston striking a valve

5.1.2 Double Overhead Cam:

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.

Fig 5.1.2 Double Overhead Cam

Lift Curves:

The purpose of the cam lobe is to raise the lifter and open the valve. You can look at the lobe, but it doesn't tell you exactly how it is going to do its job. The lift curve is a more precise way to look at the cam lift.

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It is a graph of the lifter (or valve) motion as the cam rotates. Below is an example for a cam with 251 degrees of duration at 0.050 lift. The lift curve can be measured using a degree wheel and dial indicator or more accurately using a computer driven cam profiling system. The opening intake ramp and flank and the intake nose are indicated on the graph. The ramp does not extend much beyond the valve opening, usually less than 0.015 in (0.4 mm) lift. After the ramp, the large upward curvature indicates the start of the flank. The nose portion is the large central area with negative curvature.

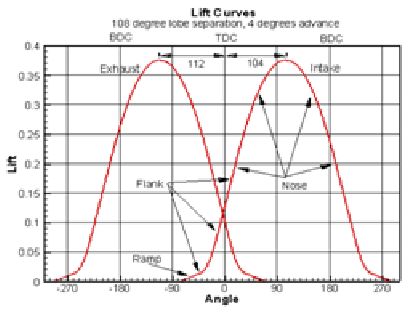

Fig 5.3 Lift Curve

CALCULATIONS

Calculations for camshaft:

Diameter of bore (Dbore) = 49mm = 0.049 m.

Length of stroke (L) =52mm =0.052m

For continuity equation,

$A \times V = C$

$Ac = \pi/4(Db^2)$,

where Ac = Area of cylinder

$= \pi/4\ (0.049)^2$

$= 1.8857 \times 10^{-3}\ m^2$

$V = 2LN/60$

N = Speed of piston

$= 2 \times 0.052 \times 8000/60$

= 13.866 m/s

$Q = Ac \times V = C$

$Q = 1.8857 \times 10^{-3} \times 13.866$

$= 0.0261\ m^3/sec$

Inlet valve:

Velocity = 85 m/s

$\pi/4\ dip^2 \times Vip = Ac \times V$

Vip = velocity of inlet port.

$\pi/4\ dip^2 \times 85 = 0.0261$

dip = diameter of inlet port.

$dip^2 = 0.0261 \times 4/(\pi \times 85)$

$= 3.9095 \times 10^{-4}$

dip = 0.0197 m.

Lift of valve hip = $dip/4\cos\alpha$ + 1mm

$= 0.01975/\ 4\cos45\ 10^{-3} + 1$

$[\propto =45]$

$= 7.9907 \times 10^{-3}m.$

Exhaust valve:

Velocity = 95 m/s

$dep^2 \times Vep = Ac \times V$

Vep = velocity of exhaust port.

$dep^2 \times 9 = 0.0261$

$dep^2 = 0.0261 \times 4/\ (95 \times \pi)$

$= 3.4980 \times 10^{-4}$

dep2 = 0.0187 m

List of valve = $dep/4\cos\alpha$ +1mm

hep = $0.0187/4\cos45 + 1\times10^{-3}$ hip ,

hep = heights of inlet and exhaust ports.

$= 6.6114 \times 10^{-3} +1$

$= 7.6114 \times 10^{-3}$ m.

Angle of ascent, $\phi_a = 58^\circ$

Angle of descent, $\phi_d = 58^\circ$

Design Of Camshaft:

From empirical relation,

Diameter of camshaft = $(0.16\times Dbore) + 12.7$

$= (0.16 \times 0.049) + 12.7 \times 10^{-3}$

= 0.02054 m

$= 0.02054 \times 10^3$ mm

= 20.54 mm (Approximately 21mm)

Base circle diameter:

Dbase circle = Dcamshaft+ 3mm

= 21+3

= 24 mm

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Width of cam:

(Wc) = (0.09 × Dbore) + 6 ×10-3

= (0.09 0.049) + 6 ×10-3

Wcam = 10.41mm

Forces:

Force (F) = Ffollower + Rrocker arm

Forces on inlet cam:

Frockerarm = Fs + Fa + Ff

Fs = π/4 d iv 2 × ps

Fs = spring force.

div = dip+ 2(0.05 dip to 0.07 dip)

= 0.0197 + 2(0.05 × 0.0197)

= 0.0220 m.

dv = Valve diameter.

Ps = maximum suction pressure < atmospheric pressure = 0.01N/mm2

Fs = π/4 (0.0220)2 × (0.01)

= 3.38013 × 10-6 N/mm2

Fva = mv × av.

mv = 8grms.

Speed of camshaft (N) = 8000/2

= 4000rpm.

In degrees per sec = 4000/60 × 360˚

= 2400˚/sec.

t = 58˚ /24000˚

= 2.4166×10-3 sec.

Acceleration:

hv = ut + ½ avt2 [u=0]

7.99 ×10-3 = (0) (2.4166 × 10-3) + 0.5×av× (2.4166 ×10-3)2

7.99×10-3 = 0 + 2.9210 ×10-6 av

av = (7.99 ×10-3)/(2.9201 × 10-6)

av = 2736.1712 m/s2

Fva = 8×2736.1712

Fva = 21.889 N

Fa = acceleration force.

Ff = Inertia force

= mf × af

=40×af

af = hf× ϖ 2/ϕ a2×4

ϖ =2×π×N/60

=2×π×4000/60

=418.87rad/sec

ϕ a=58˚

=58×π/180

=1.0122rad

af = (7.99×10-3) × (418.87/1.0122)2×4

= (7.99×10-3) ×171248.1339×4

= 5473.090 m/sec2.

Ff = 40×af

= 40×5473.09

= 218923.6143

= 218.923 N.

Ft = Fs + Fa + Ff

= 3.8013 + 21.889 + 218.923

= 244.6133 N.

Force on Exhaust Cam:

Fe = Fs + Fa + Fg + Ff

Fs = π/4dev2 × Ps

dev = dep + 2 × (0.05 dep to 0.07 dep)

= 0.0187 + 2 * 0.06 *0.0187

= 0.0209 m.

Ps = 0.01 N/mm2

Fs = π/4 × (0.0209)2 ×0.01

= 3.4306 ×10-6

= 3.4306 N

Fa = mv ×av

mv = 8 gms

N = 8000/2

= 4000rpm

In degrees per second = 4000/60 ×360˚

= 24000˚/sec

t = 58/24000

= 2.4166 ×10-3 sec

Acceleration:

hv = ½ ×av ×t2

7.6114 ×10-3 = 0.5 ×av × (2.4166*10-3)

av = (7.6114×10-3)/(2.9201×10-6)

= 2606.5545m/sec2

Fa = mv ×av

= 8*2606.5545

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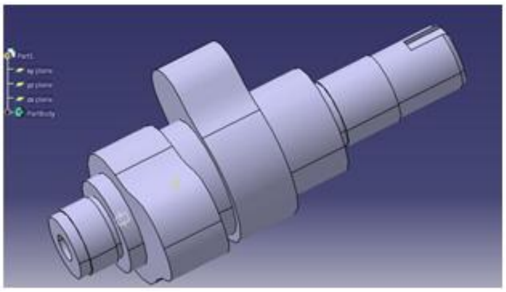
$= 20852.4365$
$= 20.8524$ N.
$F_f = m_f \times a_f$
$m_f = 40$gms
$a_f = h_v \times (\varpi\ 2/\phi\ a2) \times 4$
$= 7.6114 \times 10^{-3} \times (418.887/1.0122)^2 \times 4$
$= 5213.7521$ m/sec2
$F_f = 40 \times 5213.7521$
$= 208550.0874$
$= 208.5500874$ N
$F_g = \pi/4 \times d_v^2 \times P_{max}$
$P_{max} = 5.25$ kw
$I.P = P_m L A N/60$
$5.25 \times 10^3 = P_{max} \times 0.0521 \times \pi/4 \times (0.049)^2 \times 4000/60$
$P_{max} = 5.25 \times 10^3/6.5372 \times 10^{-3}$
$= 803091.7738$ N/m2
$F_g = \pi/4 \times d_{ev}^2 \times P_{max}$
$= \pi/4 \times (0.0209)^2 \times 803.091$
$= 275.516$ N
$F_e = 3.4306 + 208.550 + 20.8524 + 275.516$
$= 508.349$ N.

Cam Design History:

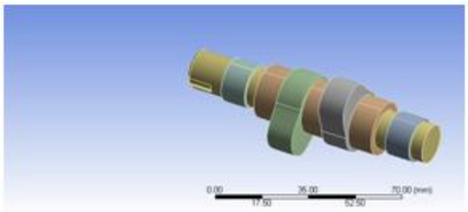
The history of cam design starting about 1906. We have somewhat limited information on non-Ford cars, but an almost complete history of Ford Cams, including the lobe designs, throughout the flathead era, i.e. thru 1953. Some of this information on Ford cams has never been available outside the Ford Archives. We are indebted to George DeAngelis and Trent Boggess for obtaining copies of original Ford drawings from the archives. We believe it is useful to look at early cam timing and cam designs, since it exposes us to the widest range of engines. This discussion is divided into the following parts:

- Timing of Early Cams - general cam timing
- Ford Flathead Cam Lobe Design - 1913 to 1953
- Post 1950 Cam Design

CATIA MODEL



Structural Analysis Of Camshaft Using Nickel chromium molybdenum steel:



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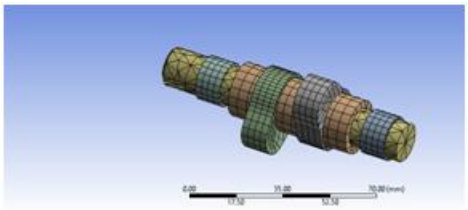

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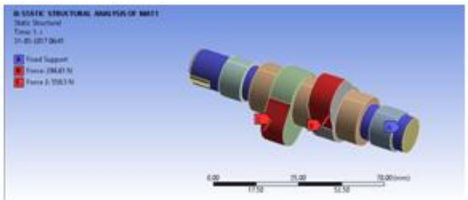

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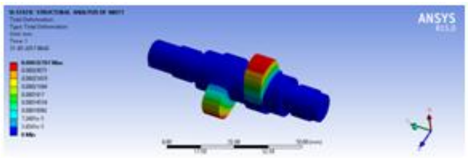

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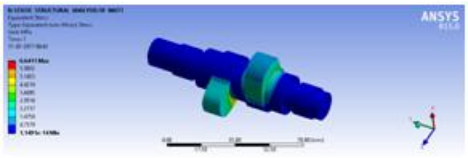
Von Mises stress:



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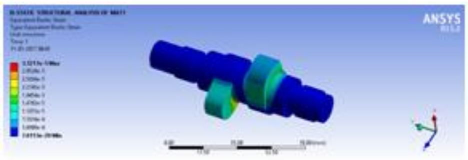
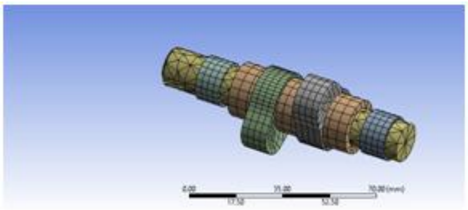


Model Analysis Of Cam Shaft Using Nickel chromium molybdenum steel:

Meshed model:



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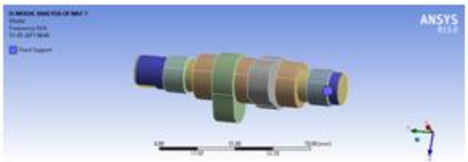

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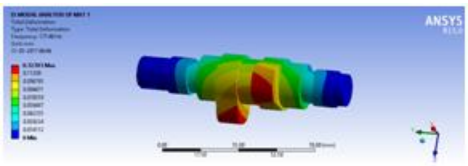
3	213.49
4	432.86
5	436.78
6	490.43

MODEL-1



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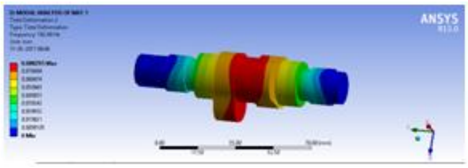

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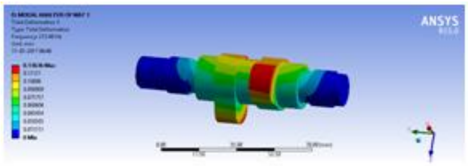

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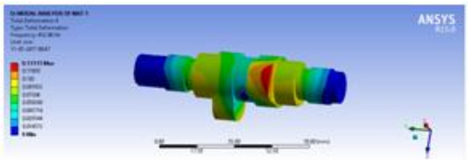

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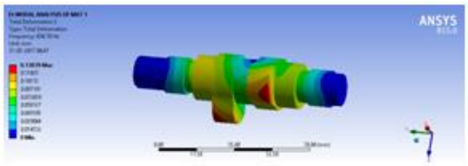

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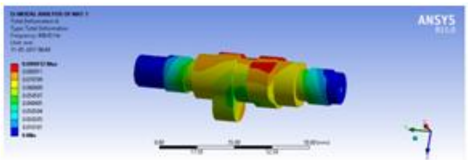
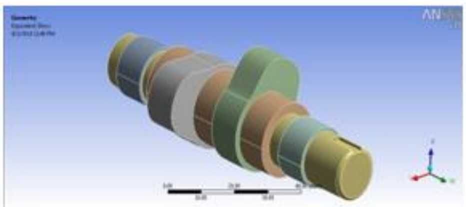


Structural Analysis Of Cam Shaft Using GRAY CAST IRON



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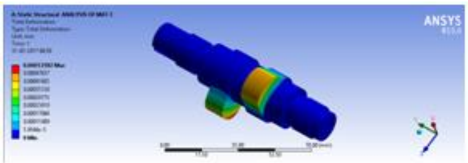

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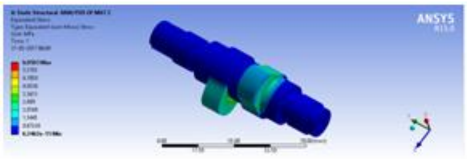

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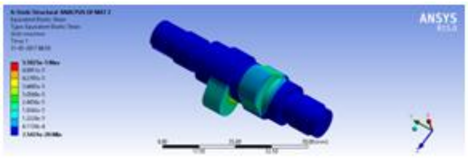
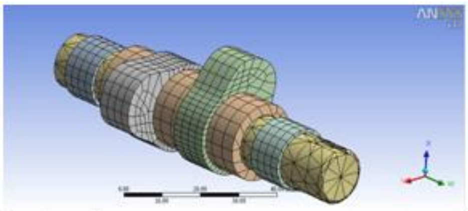


Modal Analysis Of Cam Shaft Using Gray Cast Iron:

Meshed Model:



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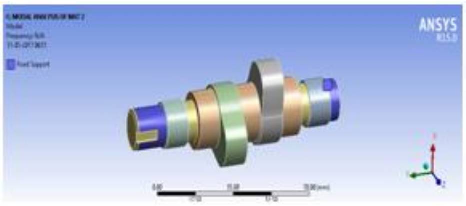

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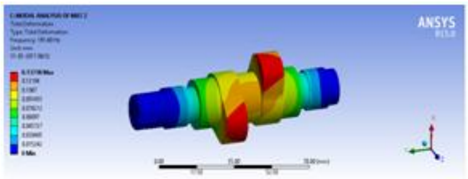

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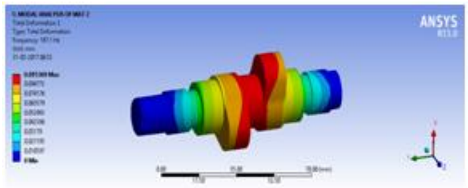

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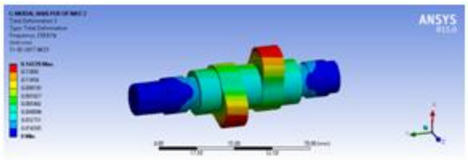

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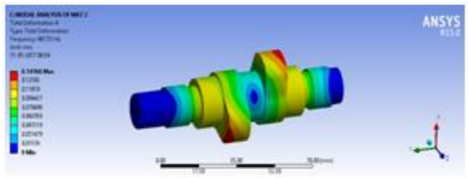
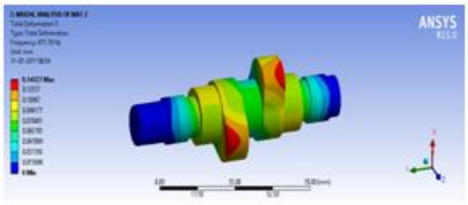
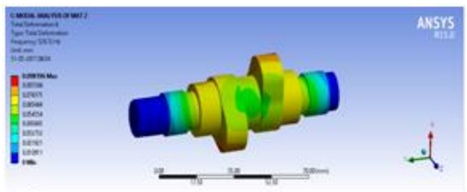


MODEL-5



MODEL-6



RESULT AND DISCUSSION

On performing structural analysis and modal analysis of camshaft using both the materials, the following results were obtained.

- From structural analysis, the displacement and stress values of camshaft using cast iron an nickel chromium molybdenum steel are as follows:

	Displacement(mm)	Stress (Mpa)
Nicke chromium molybdenum steel	0.32E-3	6.6411
Cast iron	.53e-3	6.0503

- From the above table, it is clear that camshaft displaces less in case of nickel chromium steel when compared to cast iron.
- From modal analysis, the modal frequency of camshaft using cast iron and nickel chromium molybdenum steel are as follows:

Frequency	Cast Iron	Nickel Chromium Molybdenum Steel
1	191.68	177.46
2	197.1	182.48
3	230.6	213.49
4	467.55	432.86
5	471.78	436.78

- From the above table, as the modal frequencies for camshaft using nickel chromium molybdenum steel is more compared to cast iron.

	Cast Iron	Nickel Chromium Molybdenum Steel
Factor of Safety	3.738	11.432

- On comparing all the above results, camshaft made of nickel chromium molybdenum steel is preferred.

CONCLUSION:

In this project Design and Model Analysis of camshaft is done by using CATIA and ANSYS software. By using ANSYS the model analysis is done to find out the natural frequencies of Cam. The displacement and stress are calculated.

The design of the cam is done by using CATIA software. The design is done by using cam profile at inlet and outlet (exhaust). The Cam have knife edge follower. The structural analysis is used to find the stress and displacement values in Cam. The model analysis is used to find the natural frequencies of the camshaft and the safety of factor is also considered. In this project the preferred material for Cam is selected at it's working environment. The material selection is done by considering stress, displacement and natural frequencies of the materials. The material selection for Cam is done by using ANSYS software. In this the two materials are compared. The stress and displacements are calculated at inlet and outlet of Cam. Finally the nickel chromium molybdenum steel is preferred.

REFERENCES:

1. Machine Design by R.S.KHURMI&J.K.GUPTA.
2. Theory of machines by sadhu singh
3. Theory of Machines by R.S.KHURMI
4. Model Analysis By Brian J. Schwarz & Mark H. Richardson Vibrant Technology, Inc. Jamestown, California 95327
5. Potter, R. and Richardson, M.H. "Identification of the Modal Properties of an Elastic Structure from Measured Transfer Function Data" 20th International Instrumentation Symposium, Albuquerque, New Mexico, May 1974.
6. Vold, H. and Rocklin, G.T., "The Numerical Implementation of a Multi-Input Estimation Method for Mini-Computers", 1st International Modal Analysis Conference, Orlando, FL, September 1982.
7. Formenti, D. and Richardson, M. H. "Global Frequency & Damping from Frequency Response Measurements", 4th International Modal Analysis Conference, Los Angeles, CA, February 1986
8. http://wapedia/en/hydraulic_lifters
9. http://wapedia/en/sliding_friction
10. http://wapedia/en/surface_hardening
11. http://auto.howstuffworks.com/camshaft.htm
12. http://www.lmsintl.com/modal-analysis

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