CHAPTER 1

INTRODUCTION

In the automobile industry the environment demands of lower emissions, lower fuel consumption, longer service intervals and longer lifecycles are growing tougher. Therefore product development of existing parts and product systems is important. However, when making calculation models of engine parts, all aspects of the environment in which these parts work cannot be foreseen .

A cam–follower kinematic pair works under complicated conditions of mechanical load, and wears during operation. The contact surfaces of the cam and the follower are usually surface hardened. The hardening may be due to phase transformation or precipitation processes occurring in the material during heat treatment or thermo chemical treatment .

Fig 1 Diesel engine cam shaft

Machines that are driven by high-speed cams are widely used in the high-volume manufacturing of small metal parts. Cams are used to control the actions of the machines, such as stock advancement and cutting tool motion. When the machines operate at high speed, the cam motion can induce vibration that degrades the manufacturing quality. For this reason, cam design software makes the cam profiles very smooth. This paper presents a method for easily modifying cam profiles to reduce the vibration from a known flexible mode of the cam-driven system. Note that a complete cam design procedure is not presented. We assume a base line cam profile has been generated from the usual requirements of rise times, dwell times, smoothness requirements, etc.

A simple model of a cam-driven system is sketched in here. The input to the system is y(t) (the radius of cam profile) and the output of interest is x(t) (the follower displacement). The spring constant of the follower is k1 , the stiffness of the restoring spring is k2 , and the viscous damping coefficient is b. The equation of motion for this system is

$$m\ddot{x}+b\dot{x}+(k_1+k_2)x=k_1y$$

1.1 Journal of Mechanical Design

A worst-case scenario for inducing vibration in this system is when the damping is zero. Addressing this case, the transfer function for the system is

$$G(s)=\frac{X(s)}{Y(s)}=\frac{\frac{k_1}{m}}{s^2+\frac{(k_1+k_2)}{m}} \quad (2)$$

A more generalized description of the transfer function is given by

$$G(s)=A\frac{(2\pi\lambda)^2}{s^2+(2\pi\lambda)^2} \quad (3)$$

Where A is a scaling coefficient that depends on the spring and mass parameters. The dimensionless parameter, λ, is the ratio of the rise time of the cam, t_r, to the natural period of vibration of the follower, t_n

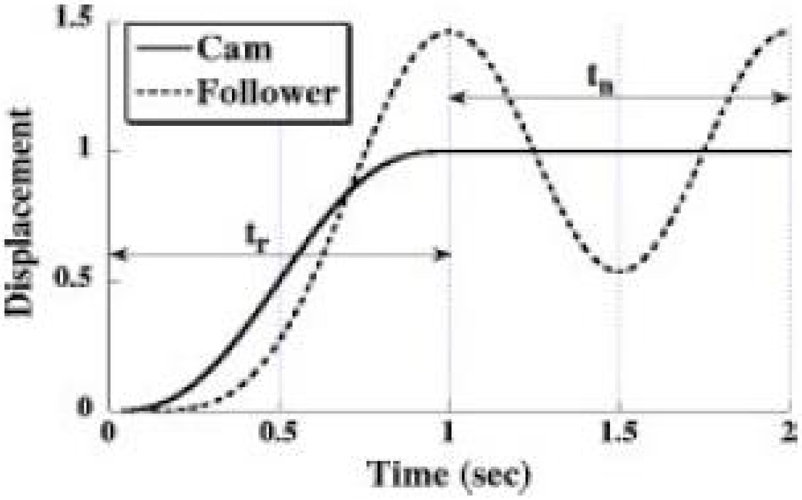


Fig. 2 Cam and follower displacement

Illustrates the definition of the variables in (4) Using time histories of the cam and follower output displacement. The figure demonstrates that even for a smooth cam profile, there can be a significant amount of vibration in the cam follower. Given this problem, large amounts of research have been conducted in order to create cam profiles that will produce small levels of vibration [1–8]. Here we investigate the use of input shaping to generate low-vibrate cam profiles.

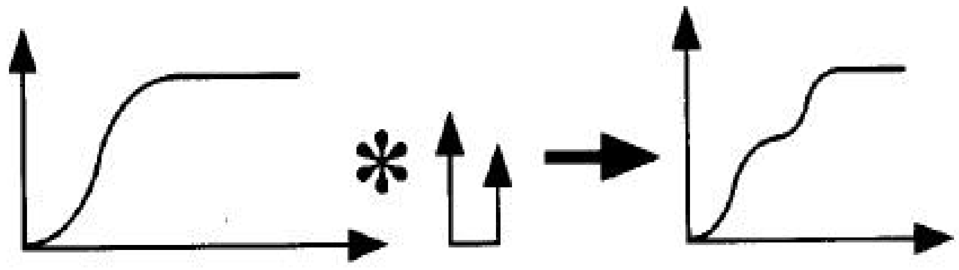


Fig. 3 The input shaping process

$$\lambda = \frac{t_r}{t_n} \qquad (4)$$

Input shaping is an open-loop control method that uses the natural frequency and damping ratio of vibration to construct a reference command that does not excite vibration [9,10]. The method starts by creating an impulse sequence, called the input shaper, which does not excite the system's flexible modes. Then, the input shaper is convolved with the original input command to

Create a function that drives the system with very little vibration. This process is demonstrated in Fig. 3, where the original command is an S-curve and the input shaper contains two impulses.

1.2 Proposed Solution: Modified Input Shaping

To reduce residual vibration of the cam follower using input shaping, three steps are taken.

1. A basic cam profile is created for specific rise and dwell requirements. For example, the dotted line in Fig. 4 shows a standard 3-4-5 polynomial profile [11] that starts at (0,0) In time and displacement and finishes its rise at (1,1).
2. The cam profile is shortened in time to compensate for the ensuing input shaping process, as shown by the dashed line in Fig. 4. (An exaggerated case of shortening has been shown to make the process clear.)
3. The shortened cam profile is convolved with the input shaper to yield the shaped cam profile, as shown by the solid line in Fig. 4. Note that the input-shaped cam profile satisfies the same boundary conditions as the initial profile.

The 3-4-5 polynomial shown in Fig. 4 is mathematically described by

$$y = 10t^3 - 15t^4 + 6t^5$$

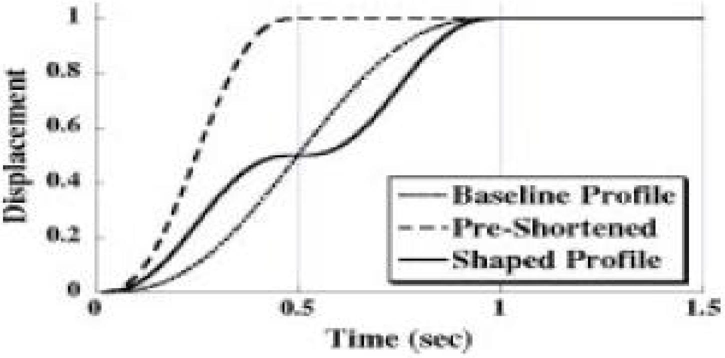


Fig. 4 Cam profiles at each of the three steps

Where *t* ranges from 0 to 1. The shortened cam profile is derived just like the standard 3-4-5 profile, but using different boundary conditions. The boundary condition on final time is reduced by the duration of the shaper.

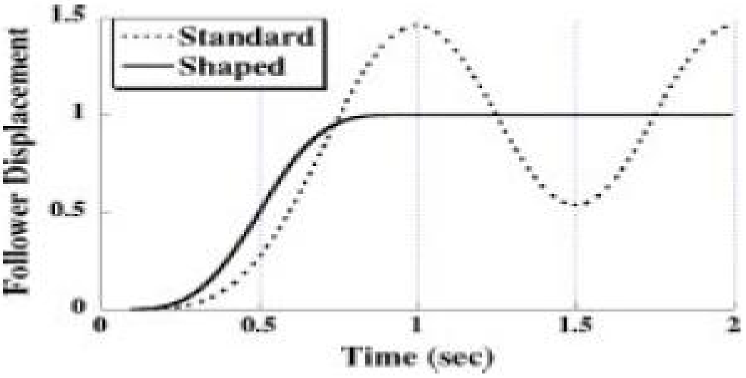


Fig. 5 Response to standard 3-4-5 polynomial and input-shaped 3-4-5 polynomial

So, instead of having boundary conditions of: (0,0) and (1,1), the shortened profile has boundary conditions of: (0,0) and (0.5,1).

The shortened polynomial becomes

$$y = 80t^3 - 240t^4 + 192t^5 \tag{6}$$

The input shaper used here contains only two impulses and is designed to suppress vibration with a period of T_d and a damping ratio of ζ. Its amplitudes, A_i, and time locations, t_i, are given as [10,12]

$$\begin{bmatrix} A_i \\ t_i \end{bmatrix} = \begin{bmatrix} \frac{1}{1+K} & \frac{K}{1+K} \\ 0 & 0.5T_d \end{bmatrix} \quad (7)$$

where

$$K = e^{\left(-\zeta\pi/\sqrt{1-\zeta^2}\right)} \quad (8)$$

The final cam profile is obtained by convolving (6) and (7). If vibration suppression is required over a large range of operating speeds, then more robust input shapers could be employed. In fact, the robustness of the input shaper could be selected to precisely target the desired range of operating speeds [13]. Note that the final cam profile does not contain any impulses.

Furthermore, the final cam profile is the same duration as the original cam profile. The convolution process involving the impulses is essentially a superposition of two scaled and time-shifted versions of the shortened profile. The vibration is eliminated because the response induced by the first profile component is cancelled by the second, time-shifted component of the profile. Figure 5 shows the simulated cam follower response to the standard 3-4-5 polynomial and the response to the input-shaped 3-4-5 polynomial. The modified input shaping process produces a cam profile that greatly reduces the vibration of the cam follower.

The results in Fig. 5 only show the cam rotating at one particular operating speed. Note that this scenario applies to many manufacturing applications. However, given that the speed of a real machine may be somewhat inconsistent, it is important that cams produce low vibration at speeds in the neighbourhood of the desired operating speed. Figure 6 compares the vibration amplitude

Produced by the standard 3-4-5 polynomial to the vibration

From the shaped polynomial over a range of operating speeds. The

Horizontal speed axis is in terms of the parameter λ given in (4),

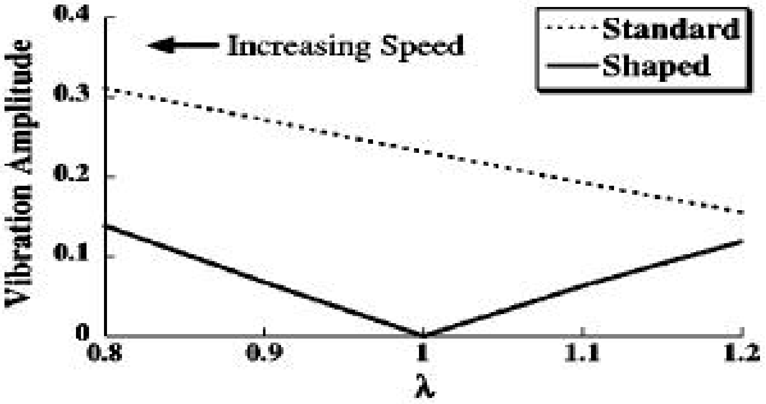


Fig. 6 Residual vibration amplitude from standard and shaped 3-4-5 polynomial at various speeds

while the vibration amplitude is a normalized value. This normalized amplitude is formed by taking the peak-to-peak vibration amplitude, after the rise portion of the profile, and dividing by the cam displacement amplitude. Holding the natural period of the cam follower constant, a higher rotating speed means that the rise time of the cam becomes smaller. Therefore, a decreasing value of λ indicates an increasing operating speed. The results indicate that the shaped cam profile keeps the vibration at a much lower level than the standard cam profile over the range of speeds shown. Zero vibration exists in the shaped response at λ = 1, which corresponds to the frequency used to design the input shaper.

1.3 Experimental Results

To further test the validity of the proposed solution, the experimental Setup shown in Fig. 7 was constructed. The setup uses a 1/4 hp electric motor to drive cams, which are up to 5 in. In diameter. The springs above and below the follower mass have identical spring constants. The resulting natural frequency of the system is 12 Hz and the damping ratio is approximately 0.05. The motor speed is accurately controlled by a feedback loop. Additionally, the gearbox ratio was chosen such that λ = 1 corresponds to the motor rotating at about 1800 rpm. Therefore, the drive system has a very large inertia compared to the cam-follower system. However, the system does not work well at slow speeds because torque variations become a problem [14].

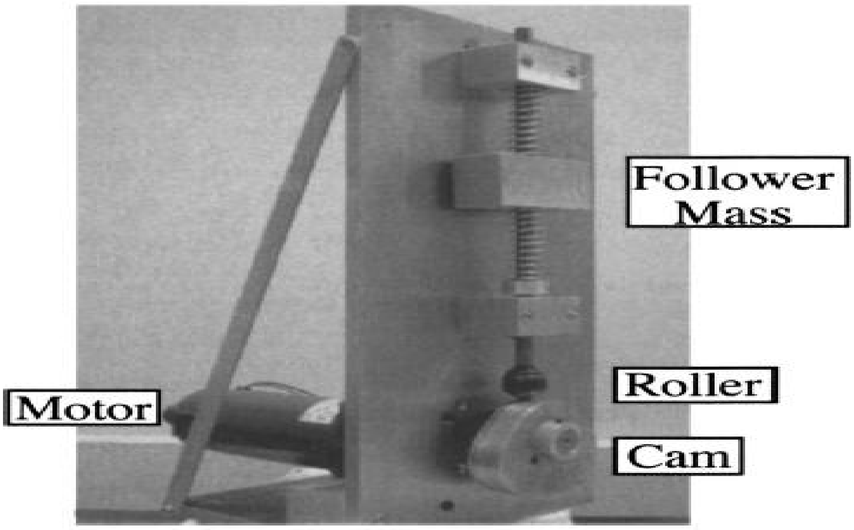


Fig 7

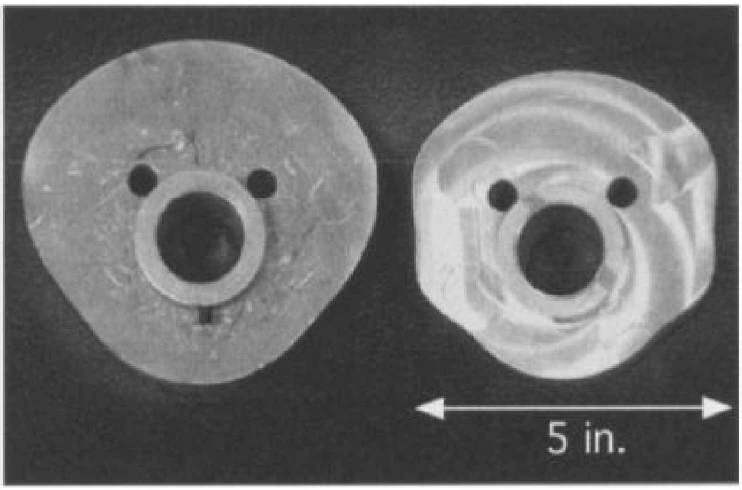


Fig. 8 Standard 3-4-5 polynomial (left) and shaped (right) cams

Cams were manufactured by first designing the profile in MATLAB and then importing the data into a CNC milling machine. Figure 8 compares a cam designed using the standard 3-4-5 polynomial on the left to an input-shaped cam on the right. A PCB Piezetronics U353 B33 accelerometer and a corresponding PCB amplifier, model 482A04, were used to measure the vibration on The follower mass. The signal was recorded on a Hewlett Packard 54501A digital oscilloscope.

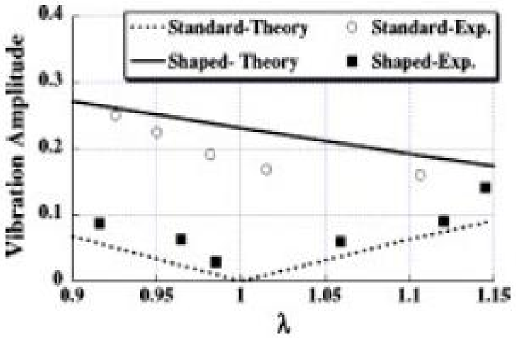


Fig. 9 Vibration amplitude response to standard and input-shaped 3-4-5 polynomial profiles

Figure 9 compares the vibration amplitude of the standard and input-shaped cams over a range of l values. The vibration is minimum for the input-shaped cam at a l value near 1, as expected. The vibration for the standard cam increases with increased operating speed ~smaller l values!. The results correspond reasonably well with the theoretical predictions. The input shaper used to create the shaped cam assumed that the system had a damping ratio of exactly zero. The mismatch between the modelling parameters and the actual hardware parameters explains why the experimental values for the shaped cam are slightly elevated about the theoretical predictions. It also explains why the values for the standard cam are slightly lower than the undammed prediction.

The primary drawback of the shaped cam appears to be increased forces at the cam/roller interface due to a slight increase in the slope of the input-shaped cam at certain points in the cycle. This may also lead to a greater risk of separation. However, this effect can be minimized by judicious design of the baseline profile and the input shaper.

1.4 Camshaft Selection:

You will see that each camshaft has a Part No and Phase No. The Part Number designates the make and model/the duration period of the inlet camshaft/the valve lift of the inlet camshaft and whether the camshaft profile is hydraulic. So if we look at the Ford 1300/1600 CVH RS Turbo XR3i XR2 Camshaft Data Sheet we see the following:-

FORC/206/420/H PH2

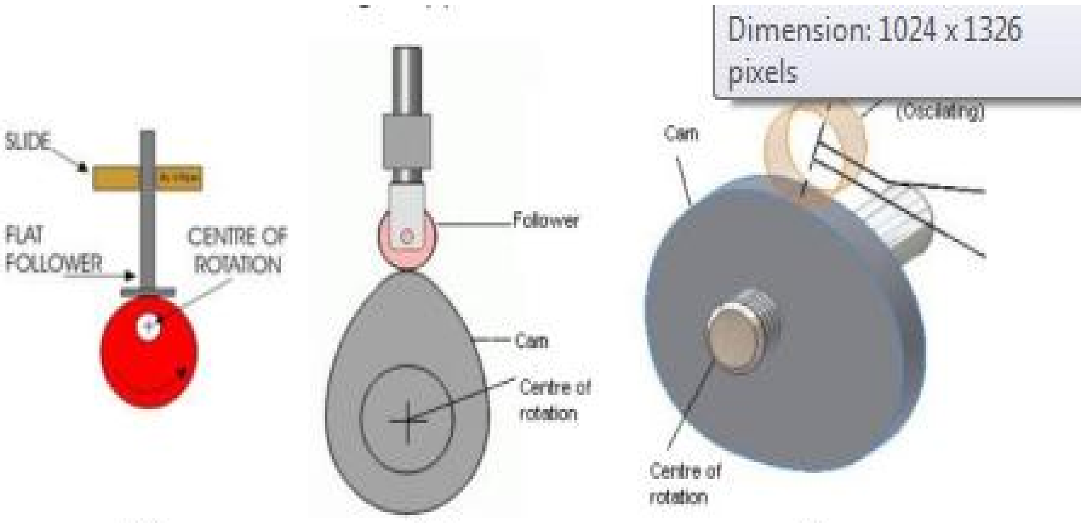
FORC	Specifies the make and engine type
260	Specifies the duration
420	Specifies the lift on the inlet valve
H	Specifies that the camshaft is designed for hydraulic cam followers
PH2	Specifies the type of use the camshaft is recommended.

1.5 Selecting Your Camshaft:

All the camshafts in this brochure have a Phase Number after the Part Number. Phases 1 to 5 will help you to select the camshaft that meets your requirements.

CHAPTER 2

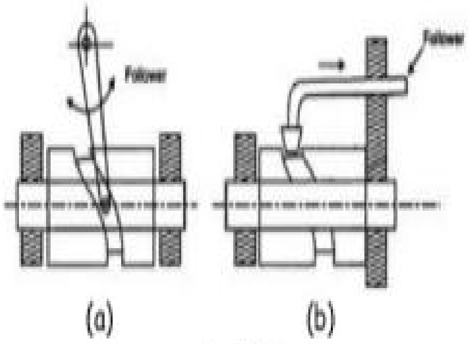
CAM & FOLLOWER



(a) (b) (c)

Fig. 3.4

d) Cylindrical cam : The shape of cam is like a cylinder having a grove on the periphery. The shape & size of the grove has been made as per design of mechanism. During working, when the arm with follower is pivoted to a fulcrum, then when cam rotates the follower will oscillate about fulcrum as shown in fig. 3.5(a). When cam rotates the follower will reciprocate along the guide parallel to the axis of cam as shown in fig. 3.5(b).

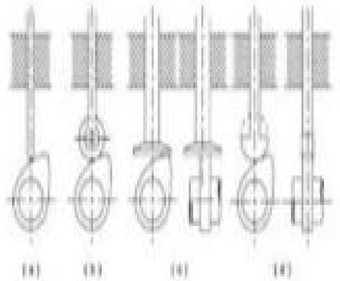


(a) (b)

Fig. 3.5

<u>TYPES OF FOLLOWERS :</u> Classification of followers is done in three ways as shown below.

1) Based on surface contact :-



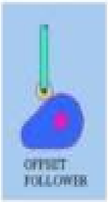


Fig. 3.7

TERMINOLOGY OF CAM :

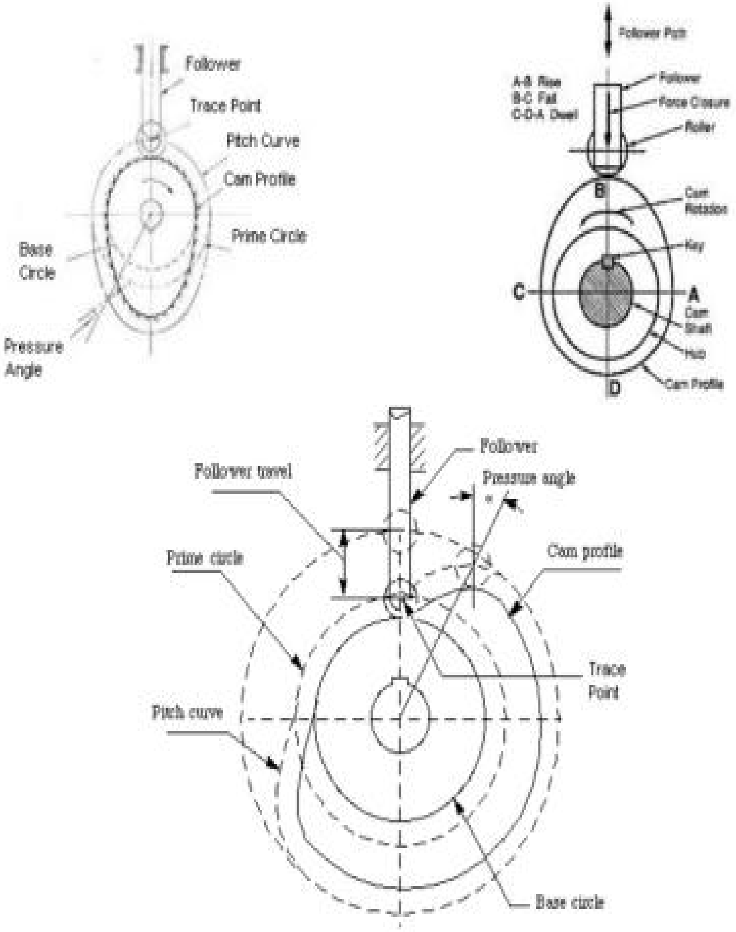


Fig. 3.8

Camshaft :

This is a camshaft that would be used for road use and will normally run with standard carb or injection system and can be fitted without additional tuning equipment. It is meant for town use and will have a smooth tick-over and will give its increase in power in the low midrange. Other modifications to the engine will increase the performance of this cam.

Fast Road Camshafts

This is a camshaft for increasing mid-range of the engines and is meant for mild competition use and where the driver requires an

Increase of power in the mid-range without suffering too much loss of power in the low-range. The tick-over will be heavier than a standard

engine. The fuel system may have to be modified and the cam will work to its optimum with modifications to the cylinder head, Inlet/exhaust system and possibly the management system.

Phase 3 (Ph3) Fast Road Rally

This type of camshaft is really the limit for normal road use. It will require fuel system and management modifications. It will have a noticeable loss of low-down power and the tick-over will be heavy. For competition use, where mid-range power is important and road use where the maximum power is required.

Tarmac Rally Sprint Race Camshaft

This camshaft is for competition use only and can be considered as a _ race cam. It could be used on the road, but would not be suitable for use in traffic. It will have a very heavy tick-over and there will be a noticeable loss of power below 3500 rpm. Its main use is for a torque race cam, giving a strong surge of power in the upper range power, yet still having the ability to floor the throttle below 5000 RPM and pull cleanly away. It will require modifications to the carb/injection system, cylinder head and induction exhaust system.

Phase 5 (Ph5) **Full Race Camshaft :**

For race use only. Not suitable for road or rally use,. Little power below 5000 RPM. Will have virtually no idle and will require crab/injection, exhaust/induction., cylinder head and engine management modifications.

MATERIAL TYPE (PERFORMANCE CAMSHAFTS)

You will note that we have a material description at the end of the camshaft specification. This informs of the following:

Billet

This means that the camshaft has been turned from a round steel bar and will normally be nitride after grinding.

We use this method for low volume production and, due to the work involved, they are always more expensive than cast blanks

Blank

Unless specified, the camshaft is made from a chilled iron casting. This is the best material for camshafts, as it has far superior wear

Characteristics than any other material.

REPRO

A regrind on an existing camshaft, only suitable for mild grinds on existing chilled iron camshafts. If you regrind case hardened steel

Camshafts you will remove the case hardening. We only regrind chilled iron cams, but prefer to supply new units

Information on Camshaft Material

Camshaft material, i.e., what the camshaft is made from, is the most important detail in stopping premature wear of performance Camshafts. There are various materials that camshafts are manufactured from Cast Iron

CHAPTER 3

CAST IRON

1.HARDENABLE IRON

This is Grade 17 cast iron with an addition of 1% chrome to create 5 to 7% free carbide. After casting, the material is flame/or induction hardened, to give a Rockwell hardness of 52 to 56 on the C Scale. This material was developed in the 1930’s in America as a low-cost replacement for steel camshafts and is mainly suited in applications where there is an excess of oil, i.e., camshafts that run in the engine block and that are splash-fed from the sump. (This is the material that the Ford OHC camshafts were manufactured from). It is not the most suitable material for performance camshafts in OHC engines.

As a company, we only use this material for performance camshafts if the camshaft is splash-fed in the sump.

2. SPHEROIDAL GRAPHITE CAST IRON KNOWN AS SG IRON

A material giving similar characteristic to hard enable. Its failing as a camshaft material is hardness in its cast form, i.e., Rockwell 5, which tends to scuff bearings in adverse conditions. The material will heat treat to 52 to 58 Rockwell. This material was used by Fiat in the 1980’s.

3. CHILLED CHROME CAST IRON

Chilled iron is Grade 17 cast iron with 1% chrome. When the camshaft is cast in the foundry, machined steel moulds the shape of the cam lobe are incorporated in the mould. When the iron is poured, it hardens off very quickly (known as chilling), causing the cam lobe material to form a matrix of carbide (this material will cut glass) on the cam lobe. This material is exceedingly scuff-resistant and is the only material for producing quantity OHC performance camshafts.

STEEL CAMSHAFTS

1.CARBON STEEL – EN8/EN9

Used mainly in the 1930 to 1945 period and is currently used for induction hardened camshafts in conjunction with roller cam followers, due to the through-hardening characteristics of the material.

2. ALLOYED STEELS – EN351 AISI 8620 and EN34 etc

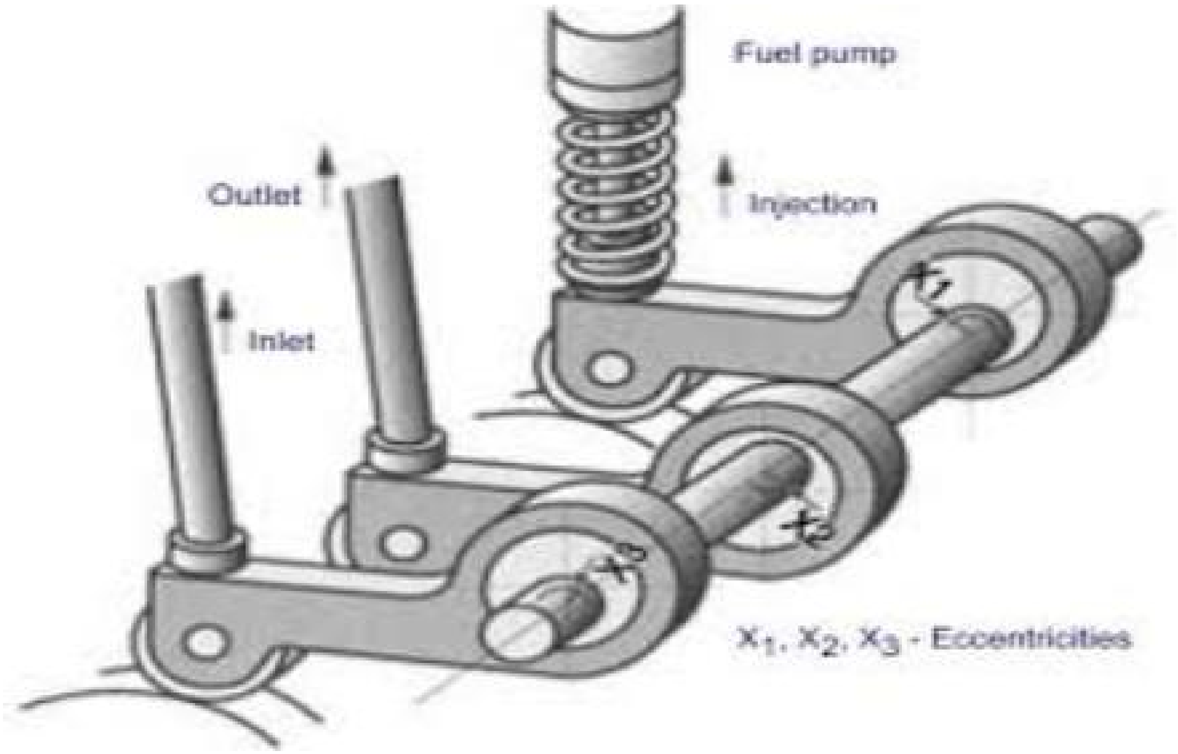
Used by British Leyland in the A Series and B Series engine and best when run against a chilled cam follower.

3. NITRIDING STEEL – EN40B

The best steel for camshafts. When nitrided it gives a surface hardness and finish similar to chilled iron. We used this when replacing chilled iron camshafts in competition engines. This material is used on several of the current F1 engines.

The automotive sector has reached a very high production capacity in the last decades. Depending on this increasing capacity, its stable growth is anticipated in the world economy. In high cycle fatigue, as the cyclic stress is comparatively low, a large fraction of the fatigue life is used in micro crack initiation. Wear is another major failure of engine camshaft material.

Here, diesel engine camshaft is made up from the EN 8D (Mildsteel) material which is one of the ductile material, so we apply von-meshes criteria. For the purpose of static structural analysis we are using ANSYS 12.1 workbench. By using this software we show the maximum stress, maximum strain and total deformation



MATERIAL PROPERTIES

PROPERTY	CAST IRON	EN 8D
Density (kg m^-3)	7200	7850
Young's Modulus (MPa)	110000	210000
Poisson's Ratio	0.28	0.3
Tensile Ultimate Strength (MPa)	170	620

CHEMICAL COMPOSITION

Carbon :	0.36-0.44%
Silicon :	0.10-0.40%
Manganese :	0.60-1.00%
Sulphur :	0.050 Max
Phosphorus :	0.050 Max

MATHEMATICAL CALCULATIONS:

1, For Fuel Cam:

1, Change in spring length: 6mm

2, C = = 8

3, Spring Constant, ks = + = 1.1840

4, Spring Load= change in spring length x ks

= 6 x 1.1840 = 7.104 kgf

5, Roller weight = 40 gm

6, Total force on cam= 7.144 kgf = 70.058 N

7, Hydraulic Pressure = 250 kg/cm^2

8, Diameter of cylinder = 6.5mm

9, Total pressure:

= (Π/4) x (Diameter of cylinder)^2 x Hydraulic Pressure

= 8.134 MPa

2, For Inlet/ Exhaust Cam:

1, Change in spring length: 5.6mm

2, Spring Load= change in spring length x ks

= 5.6 x 1.1840 = 6.6304 kgf

3, Roller weight = 50 gm

4, Push rod weight = 0.0382 kg

5, Total force on cam[6]= 6.7186 kgf = 65.88 N

s6, Gas Pressure = 2 MPa

CHAPTER 4

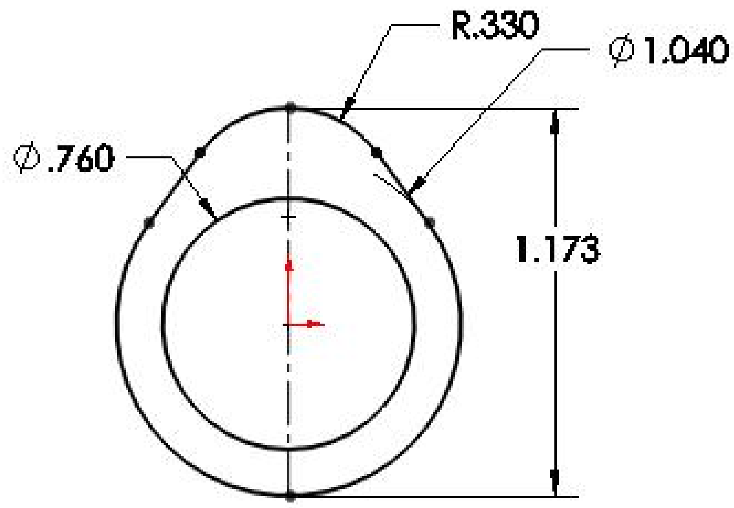
ANALYSIS OF CAM:

For the purpose of Finite Element Analysis we are using the ANSYS WORKBENCH 12.0. For the three cams we follow the step by step procedure given below and generate the maximum stress, strain and total deformation of camshaft under the loading conditions.

1, Draw the geometry of cam shaft in PRO-E 5.0/ Creo.

2, Generate Mesh in ANSYS Workbench. For any finite element analysis the total work piece divided in to finite number of small element.

<u>Design of disel engine cam follwer of CAM SHAFT</u>



Mesh Geometry of Diesel Engine Camshaft

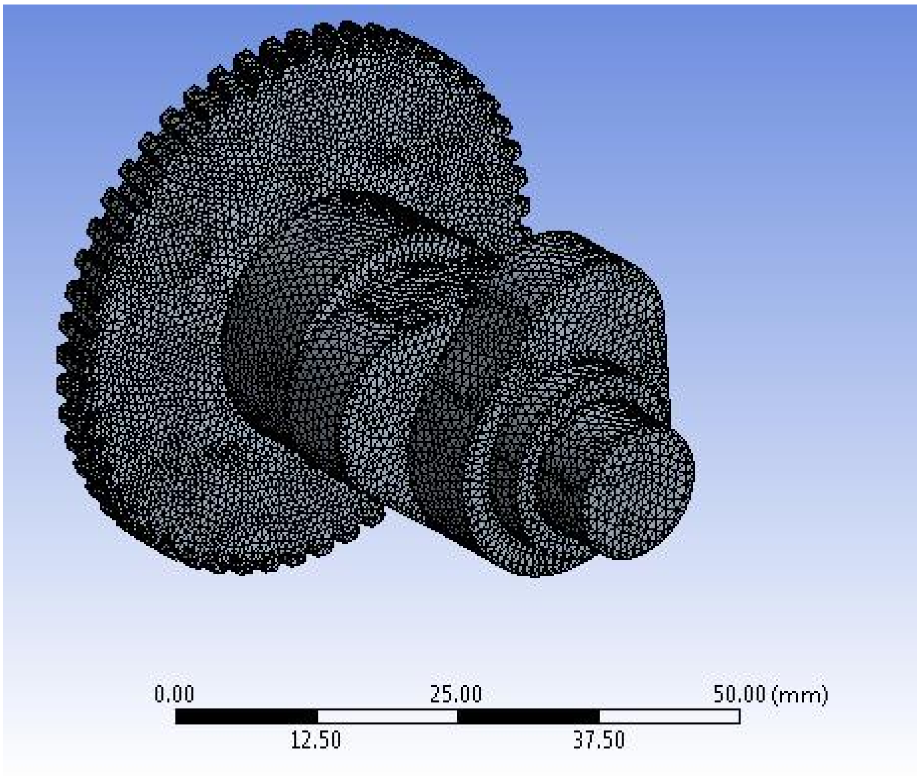


TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees RPM Celsius
Angle	Degrees
Rotational Velocity	RPM
Temperature	Celsius

Model

Geometry

TABLE 2

Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	E:\projects cad\CAM SHAFT\camshaft.igs
Type	Iges
Length Unit	Meters
Element Control	Program Controlled
Display Style	Part Color
Bounding Box	
Length X	50.8 mm
Length Y	50.8 mm
Length Z	50.8 mm
Properties	
Volume	24880 mm^3
Mass	0.19531 kg
Scale Factor Value	1.
Statistics	

Bodies	1
Active Bodies	1
Nodes	193226
Elements	116099
Mesh Metric	None
Import Using Instances	Yes
Do Smart Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\caddtek\AppData\Local\Temp
Analysis Type	3-D
Mixed Import Resolution	None
Enclosure and Symmetry Processing	Yes

TABLE 3

Model (A4) > Geometry > Parts

Object Name	*Part 1*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1

Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	EN 8D
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	50.8 mm
Length Y	50.8 mm
Length Z	50.8 mm
Properties	
Volume	24880 mm^3
Mass	0.19531 kg
Centroid X	-7.1714 mm
Centroid Y	-0.13674 mm
Centroid Z	-0.41021 mm
Moment of Inertia Ip1	28.727 $kg \cdot mm^2$

Moment of Inertia Ip2	55.894 kg·mm²
Moment of Inertia Ip3	57.193 kg·mm²
Statistics	
Nodes	193226
Elements	116099
Mesh Metric	None

Mesh

TABLE 4

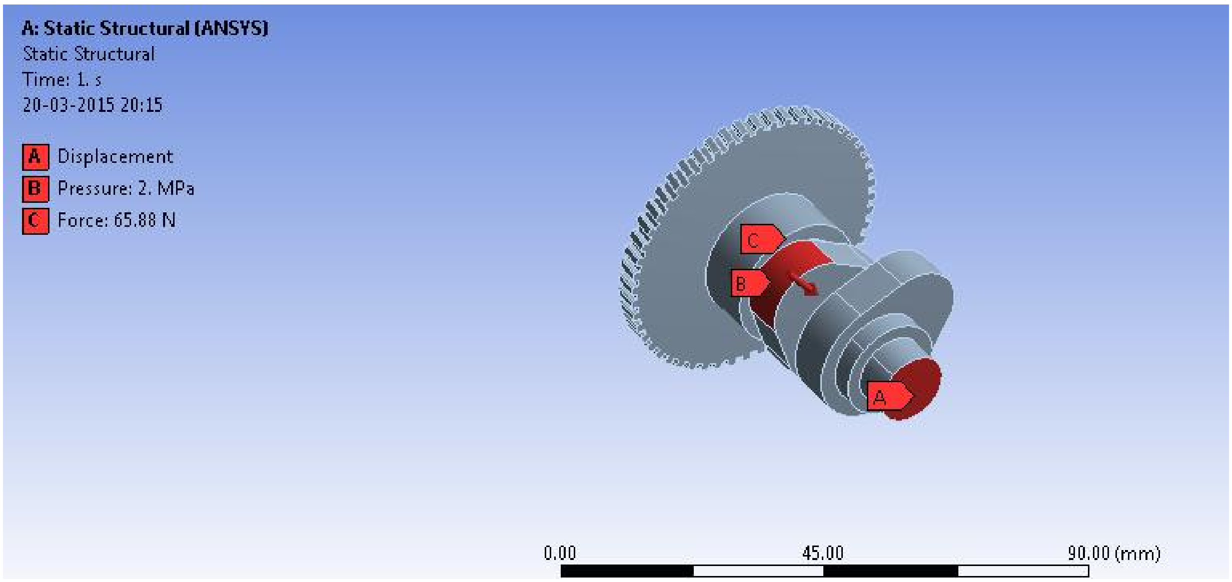
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Fine
Element Size	0.50 mm
Initial Size Seed	Full Assembly

Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	0.427940 mm
Inflation	
Use Automatic Tet Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Pinch	

Pinch Tolerance	Please Define
Generate on Refresh	No
Statistics	
Nodes	193226
Elements	116099
Mesh Metric	None

After Generate Mesh in ANSYS Workbench. We apply displacement, force and pressure conditions on all three cam, i.e.- Fuel cam, Inlet and Exhaust cam.



A: Static Structural (ANSYS)
Static Structural
Time: 1. s
20-03-2015 20:15

A Displacement
B Pressure: 2. MPa
C Force: 65.88 N

Force, displacement and pressure conditions

(Outlet cam)

Static Structural

TABLE 5

Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	ANSYS Mechanical
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 6

Model (A4) > Static Structural (A5) > Loads

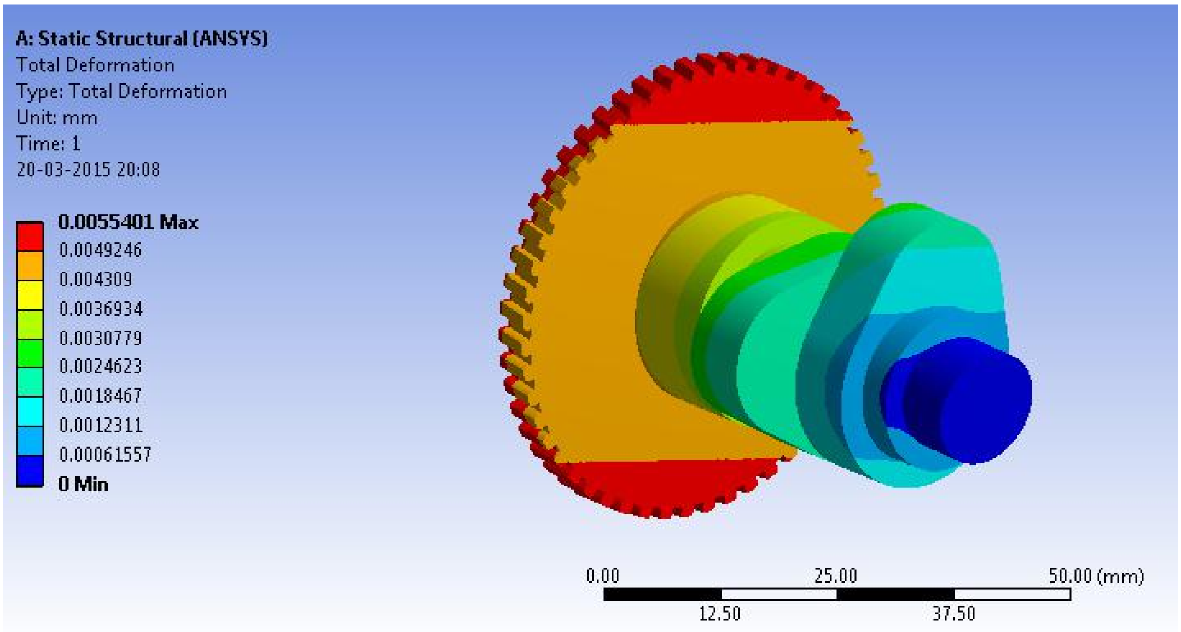
Object Name	*Displacement*	*Remote Force*	*Pressure*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Face		

Coordinate System		Global Coordinate System	
X Coordinate		11.43 mm	
Y Coordinate		3.2103e-016 mm	
Z Coordinate		-16.092 mm	
Location		Defined	
Definition			
Type	Displacement	Remote Force	Pressure
Define By	Components	Vector	Normal To
Coordinate System	Global Coordinate System		
X Component	0. mm (ramped)		
Y Component	0. mm (ramped)		
Z Component	0. mm (ramped)		
Suppressed	No		
Magnitude		65.88 N (ramped)	2. MPa (ramped)
Direction		Defined	
Behavior		Deformable	

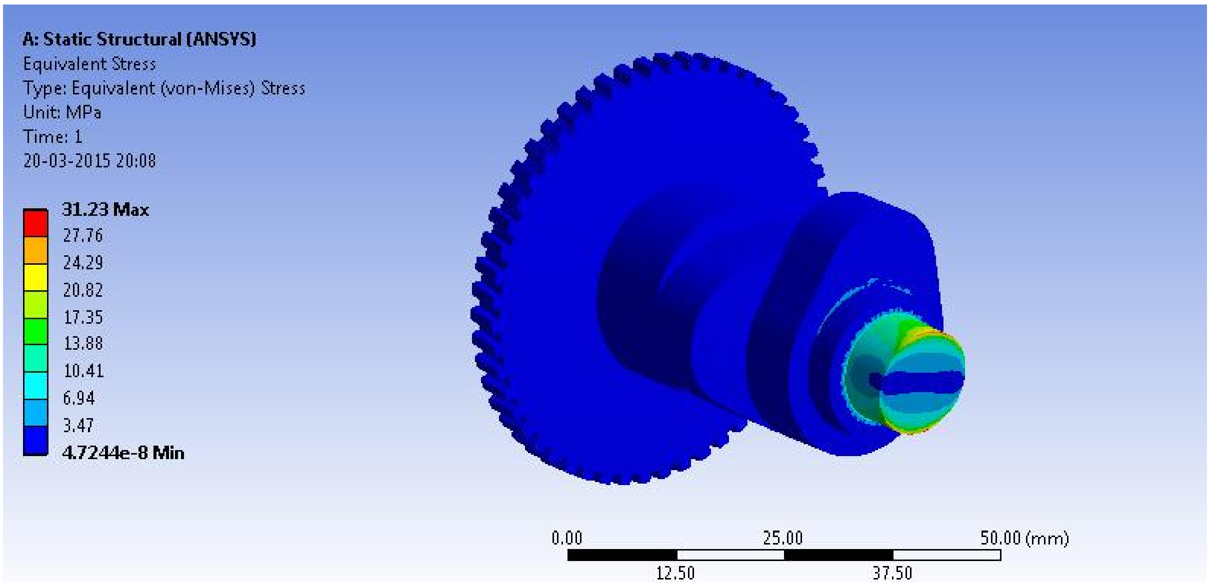
Advanced			
Pinball Region		All	

ANALYSIS RESULTS OF EN 8D CAM SHAFT

For solution select von-misses theory and apply total deformation, maximum stress and maximum strain

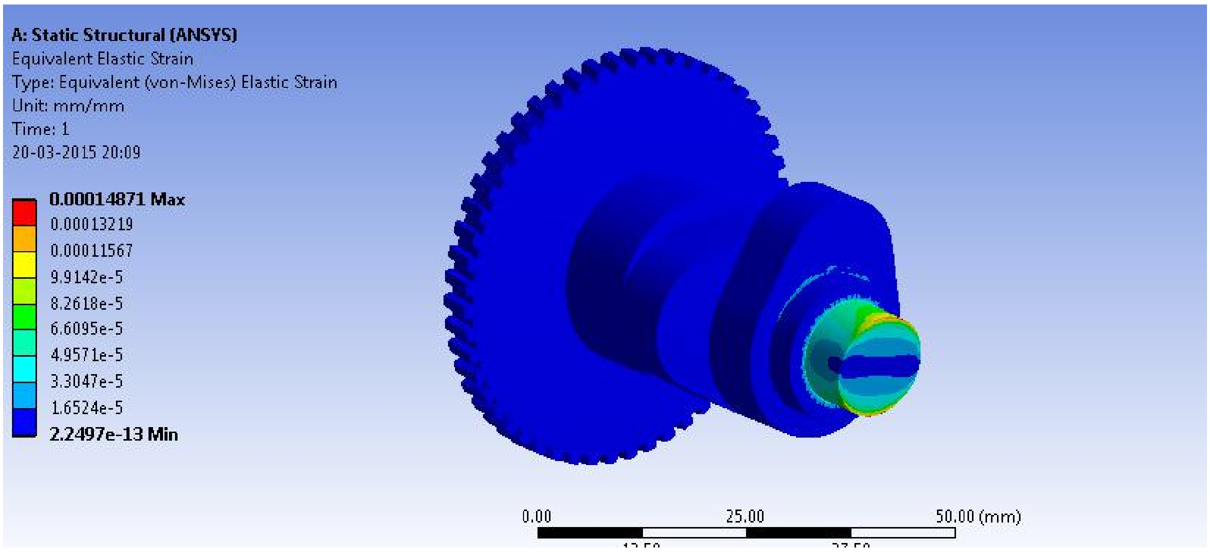


TOTAL DEFORMATION OF OUTLET CAM IN CAM SHAFT



A: Static Structural (ANSYS)
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
20-03-2015 20:08

EQUIVALENT VON MISES STRESS OF OUTLET CAM IN CAM SHAFT

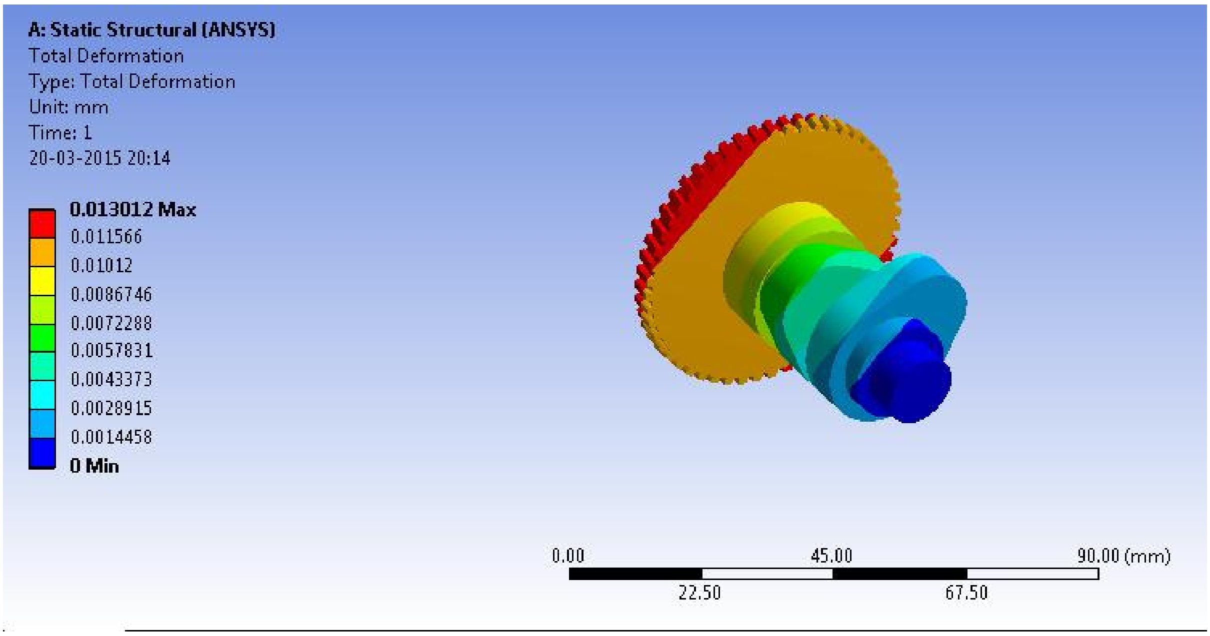


A: Static Structural (ANSYS)
Equivalent Elastic Strain
Type: Equivalent (von-Mises) Elastic Strain
Unit: mm/mm
Time: 1
20-03-2015 20:09

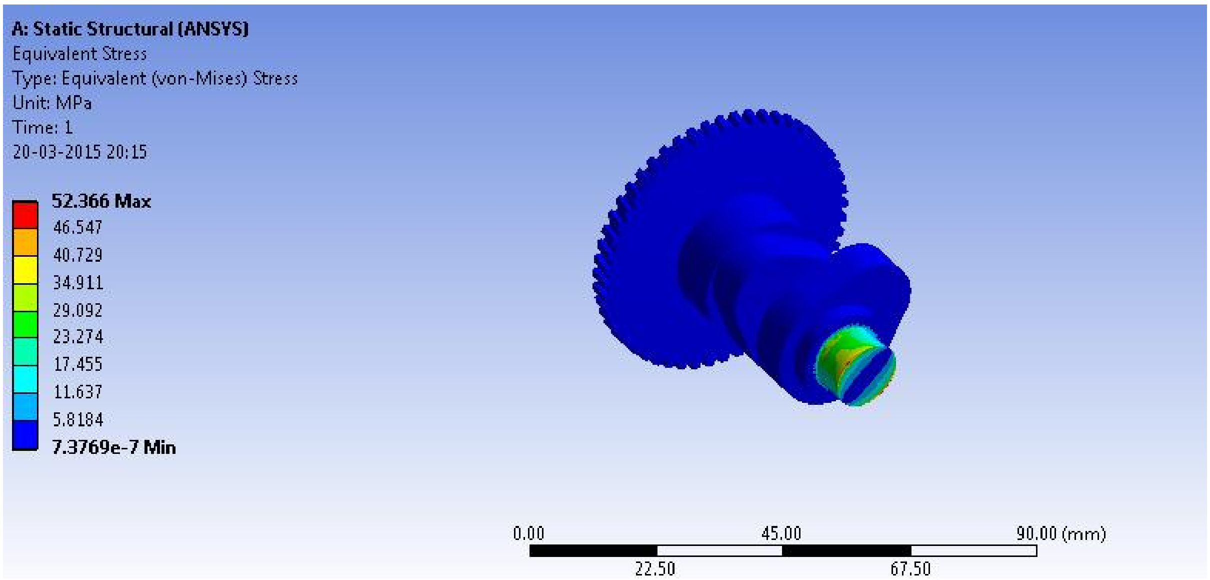
EQUIVALENT VON MISES STRAIN OF OUTLET CAM IN CAM SHAFT

Definition			
Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent (von-Mises) Elastic Strain
Results			
Minimum	0. mm	4.7244e-008 MPa	2.2497e-013 mm/mm
Maximum	5.5401e-003 mm	31.23 MPa	1.4871e-004 mm/mm

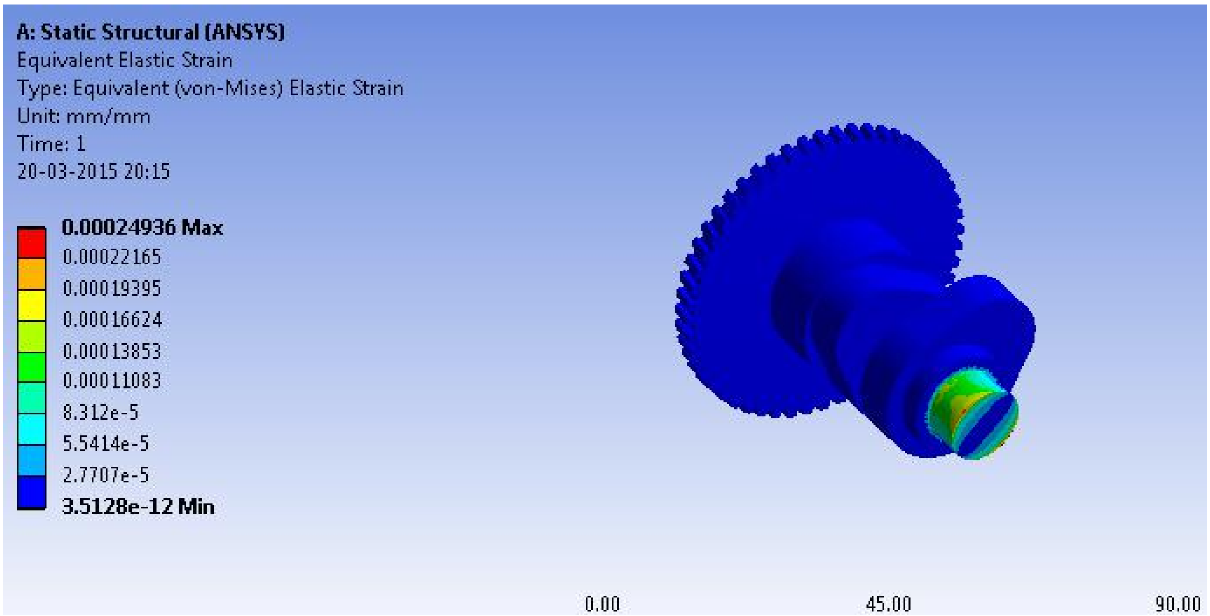
INLET CAM



TOTAL DEFORMATION OF INLET CAM IN CAM SHAFT

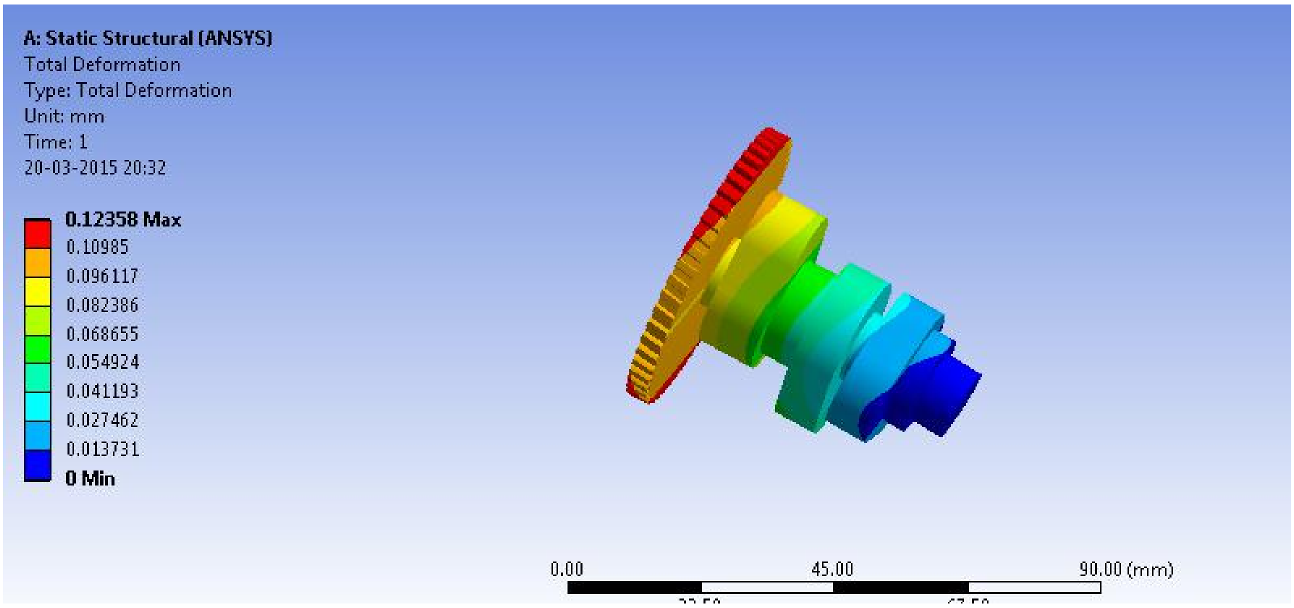


EQUIVALENT VON MISES STRESS OF INLET CAM IN CAM SHAFT

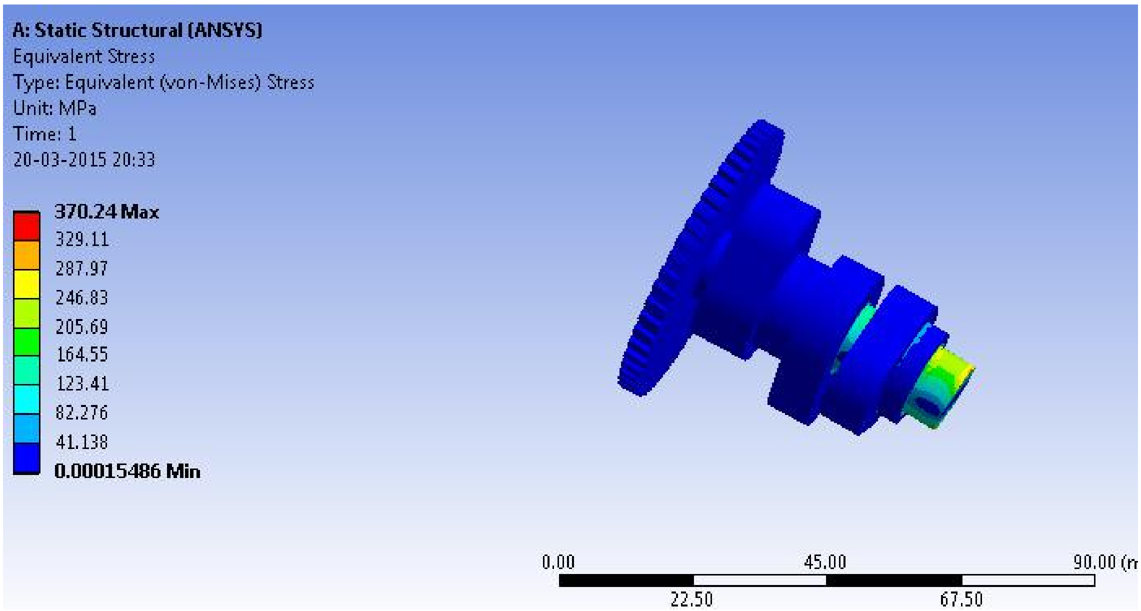


EQUIVALENT VON MISES STRAIN OF INLET CAM IN CAM SHAFT

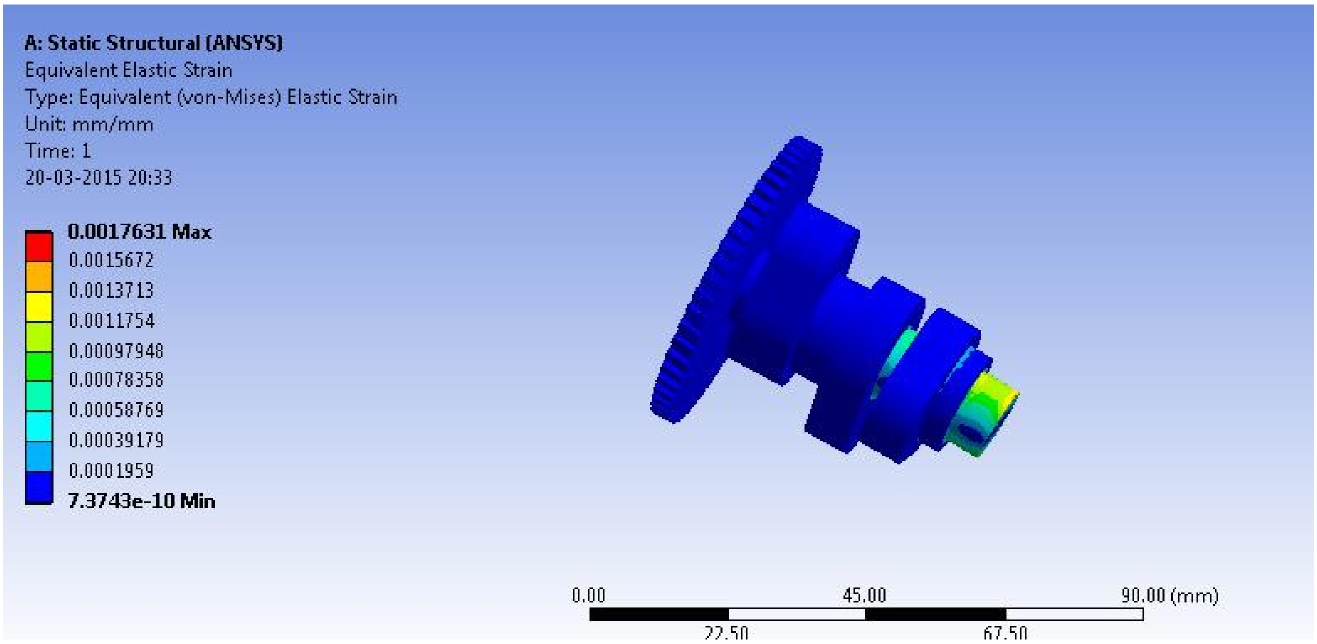
FUEL CAM



TOTAL DEFORMATION OF FUEL CAM IN CAM SHAFT



EQUIVALENT VON MISES STRESS OF FUEL CAM IN CAM SHAFT



EQUIVALENT VON MISES STRAIN OF FUEL CAM IN CAM SHAFT

ANALYSIS RESULTS OF CAST IRON CAM SHAFT

Properties	
Volume	24880 mm^3
Mass	0.17913 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	193226
Elements	116099
Mesh Metric	None
Do Smart Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\caddtek\AppData\Local\Temp
Analysis Type	3-D
Mixed Import Resolution	None
Enclosure and Symmetry Processing	Yes

Material	
Assignment	Gray Cast Iron
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	50.8 mm
Length Y	50.8 mm
Length Z	50.8 mm
Properties	
Volume	24880 mm^3
Mass	0.17913 kg
Centroid X	-7.1714 mm
Centroid Y	-0.13674 mm
Centroid Z	-0.41021 mm
Moment of Inertia Ip1	26.349 kg·mm^2
Moment of Inertia Ip2	51.266 kg·mm^2
Moment of Inertia Ip3	52.457 kg·mm^2

Mesh

Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Fine
Element Size	0.50 mm
Initial Size Seed	Full Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	0.427940 mm
Inflation	
Use Automatic Tet Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272

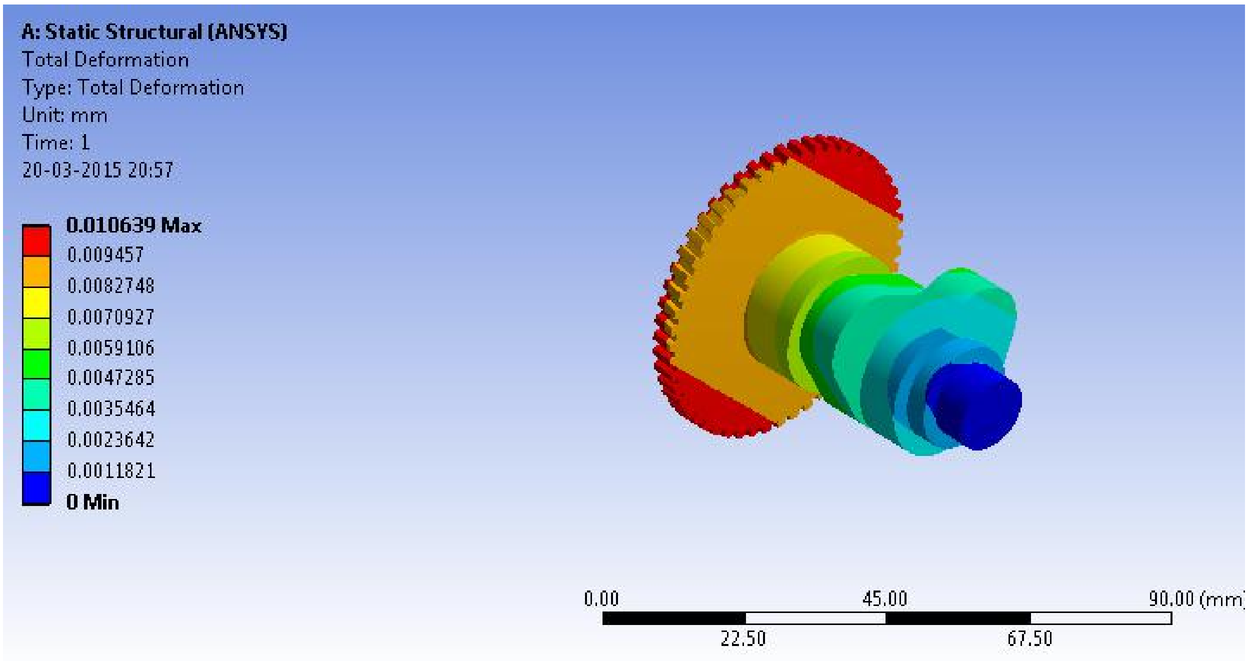
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Pinch	
Pinch Tolerance	Please Define
Generate on Refresh	No
Statistics	
Nodes	193226
Elements	116099
Mesh Metric	None

Static Structural

Model (A4) > Static Structural (A5) > Loads

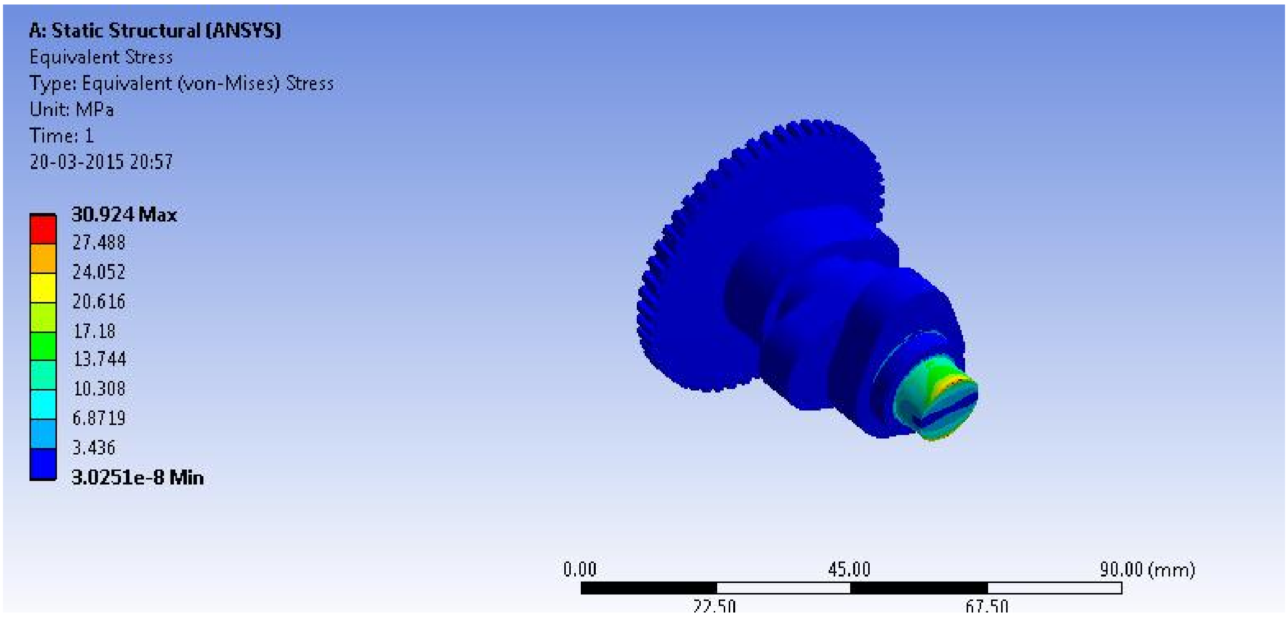
Object Name	*Displacement*	*Pressure*	*Force*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Face		
Definition			
Type	Displacement	Pressure	Force
Define By	Components	Normal To	Vector
Coordinate System	Global Coordinate System		
X Component	0. mm (ramped)		
Y Component	0. mm (ramped)		
Z Component	0. mm (ramped)		
Suppressed	No		
Magnitude		2. MPa (ramped)	68.88 N (ramped)
Direction			Defined

OUTLET



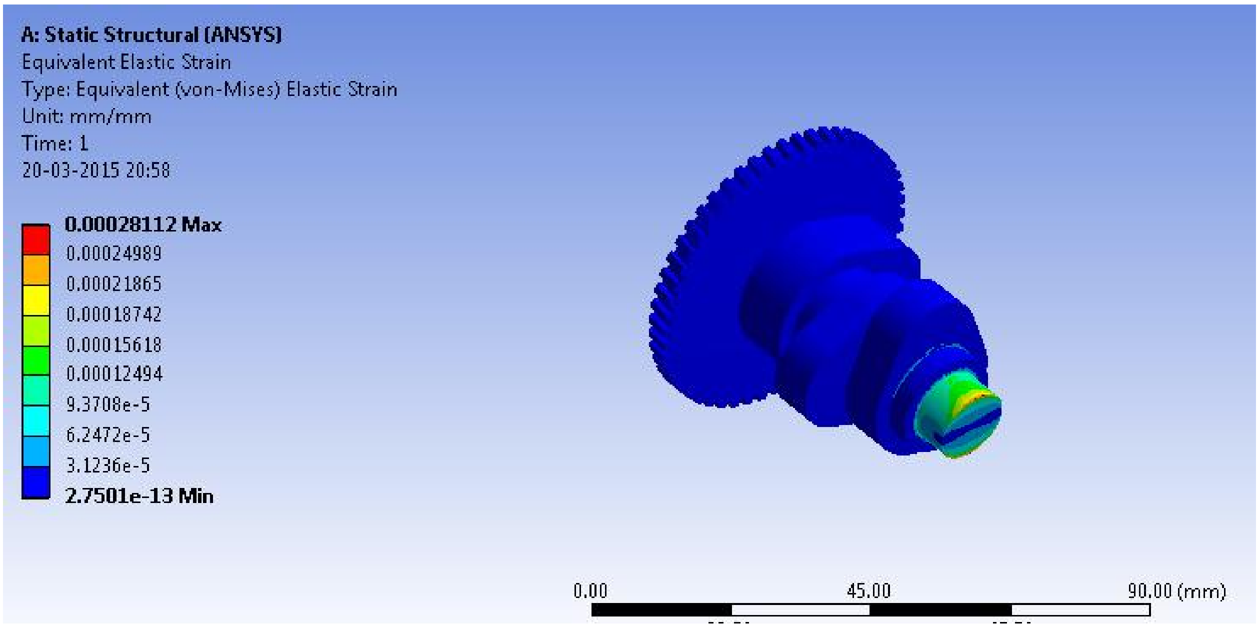
A: Static Structural (ANSYS)
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
20-03-2015 20:57

TOTAL DEFORMATION OF OUTLET CAM IN CAM SHAFT



A: Static Structural (ANSYS)
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
20-03-2015 20:57

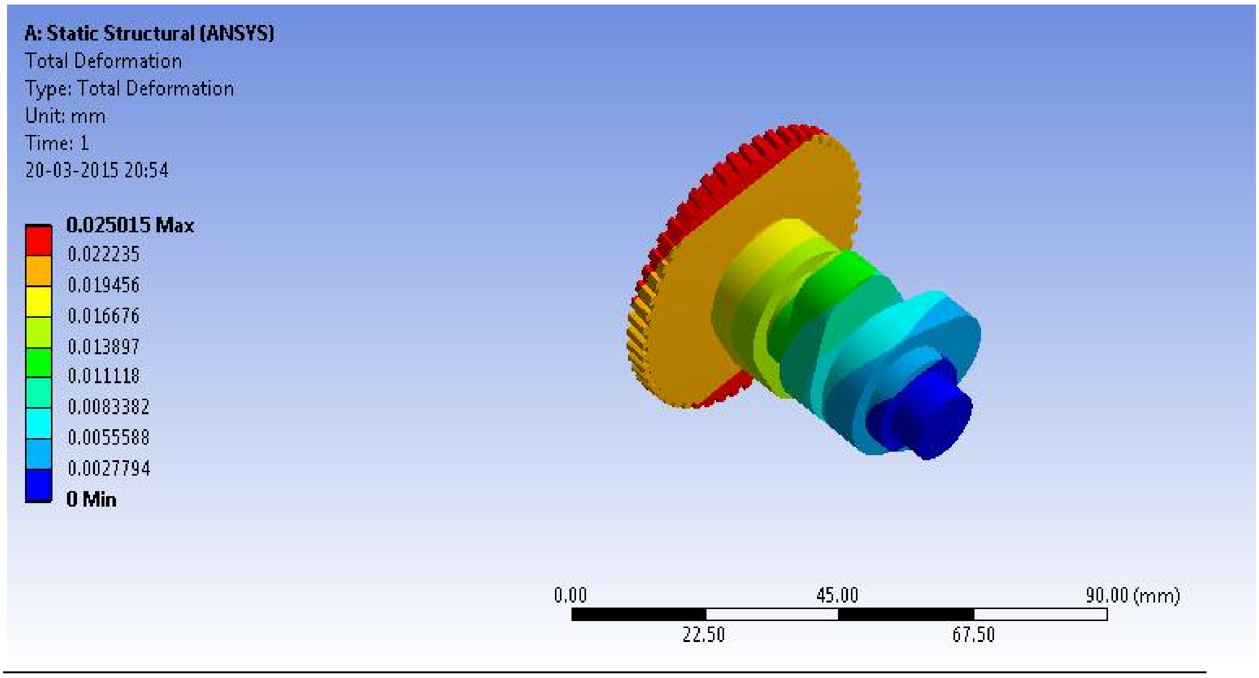
EQUIVALENT VON MISES STRESS OF OUTLET CAM IN CAM SHAFT



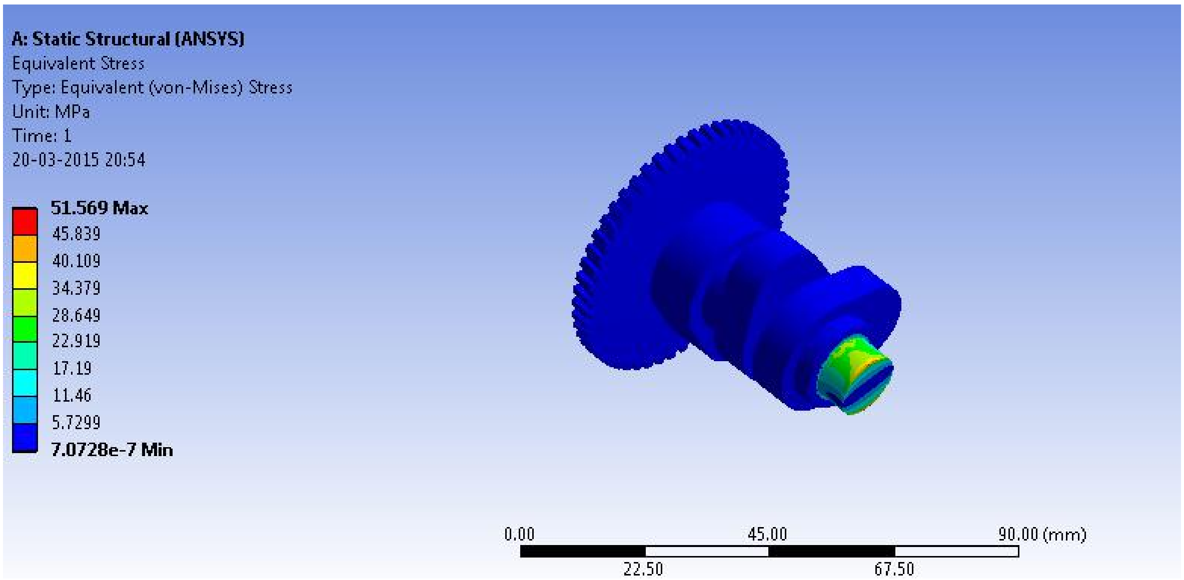
A: Static Structural (ANSYS)
Equivalent Elastic Strain
Type: Equivalent (von-Mises) Elastic Strain
Unit: mm/mm
Time: 1
20-03-2015 20:58

EQUIVALENT VON MISES STRAIN OF OUTLET CAM IN CAM SHAFT

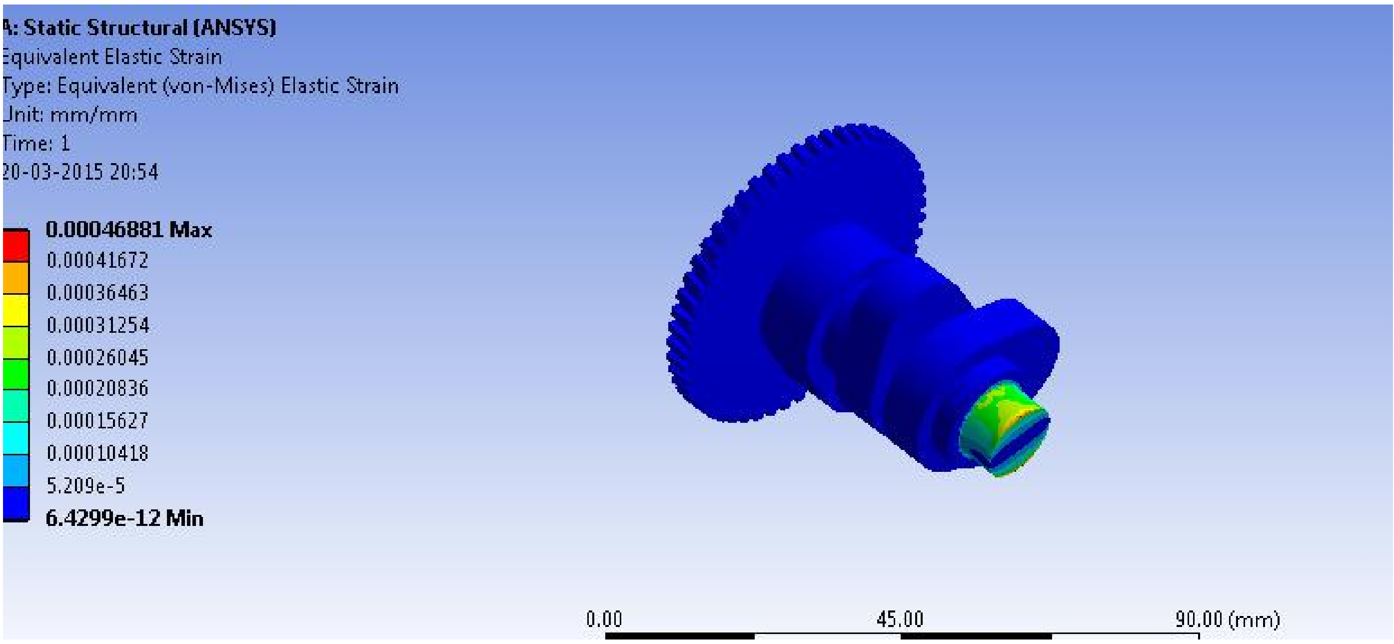
<u>INLET CAM</u>



TOTAL DEFORMATION OF INLET CAM IN CAM SHAFT

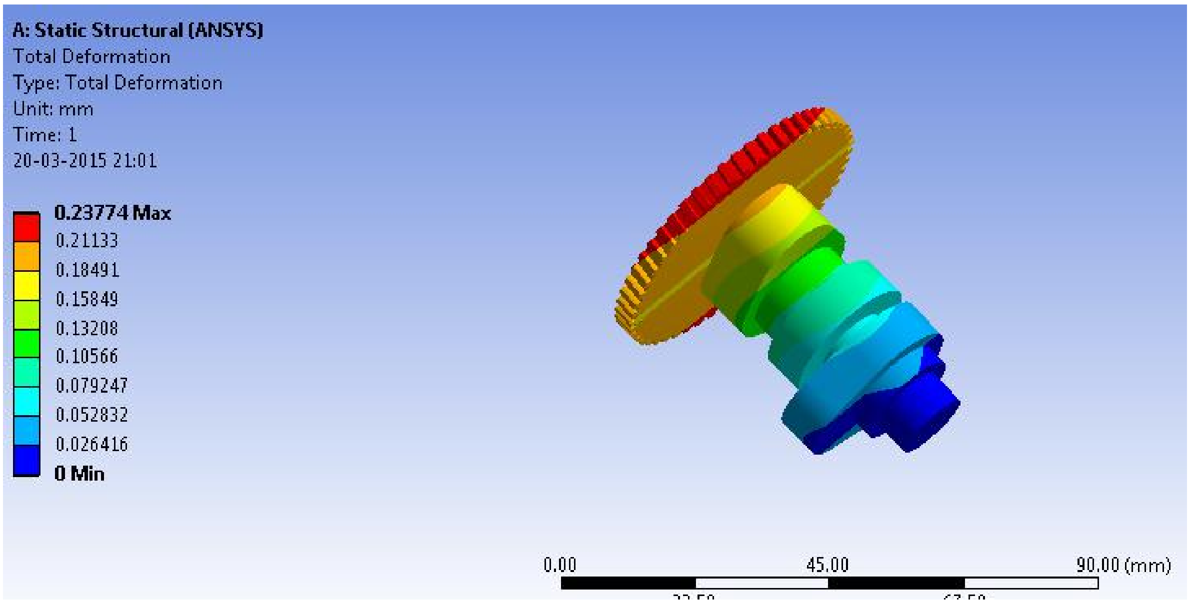


EQUIVALENT VON MISES STRESS OF INLET CAM IN CAM SHAFT

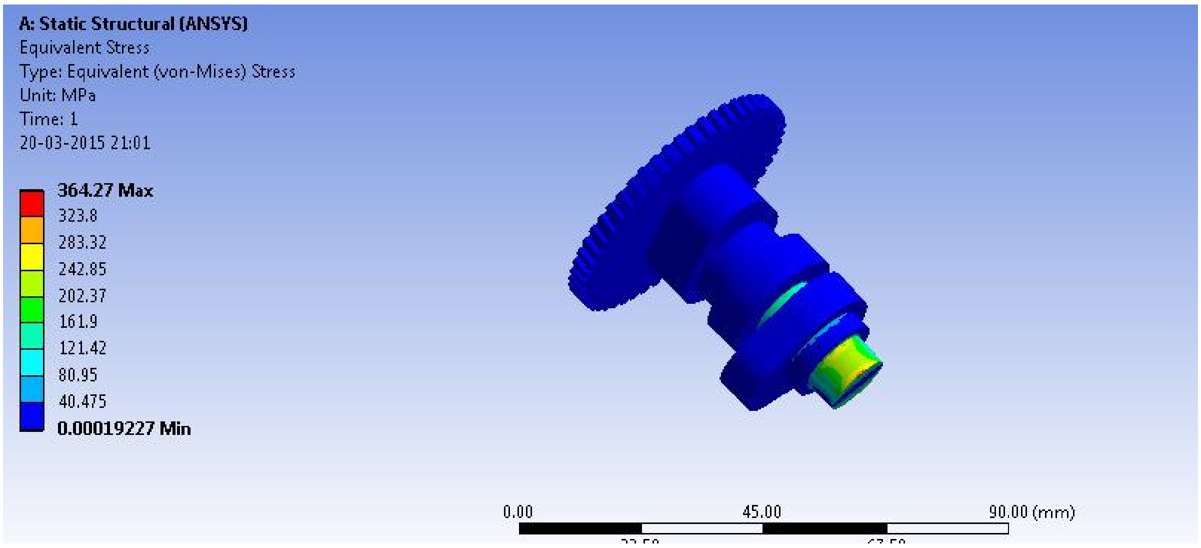


EQUIVALENT VON MISES STRAIN OF INLET CAM IN CAM SHAFT

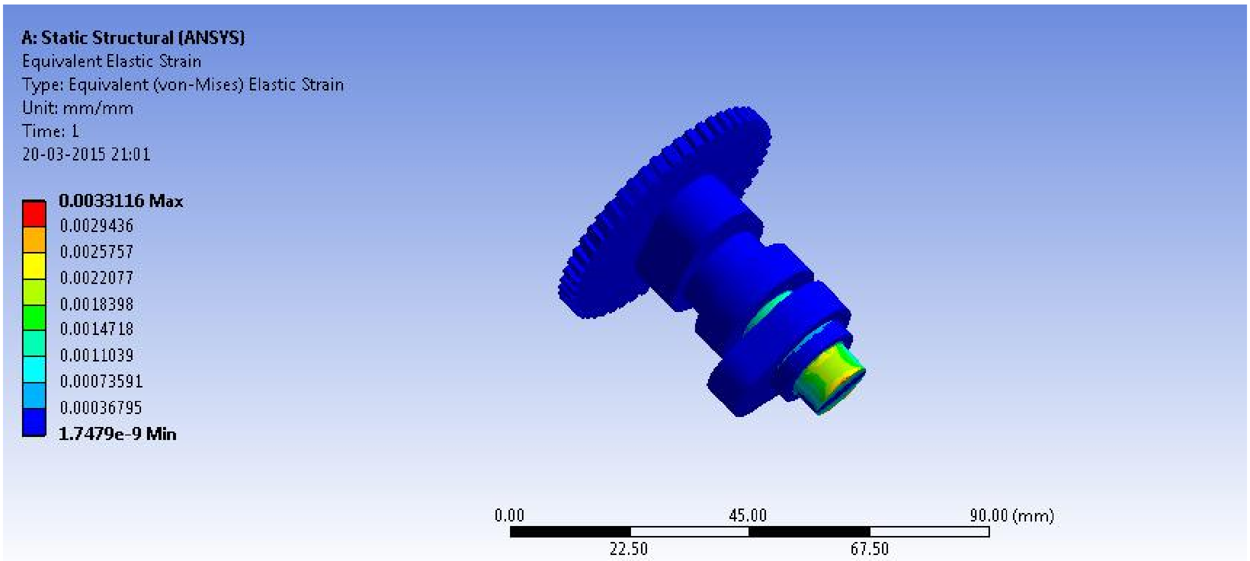
FUEL CAM



TOTAL DEFORMATION OF FUEL CAM IN CAM SHAFT



EQUIVALENT VON MISES STRESS OF FUEL CAM IN CAM SHAFT



EQUIVALENT VON MISES STRAIN OF FUEL CAM IN CAM SHAFT

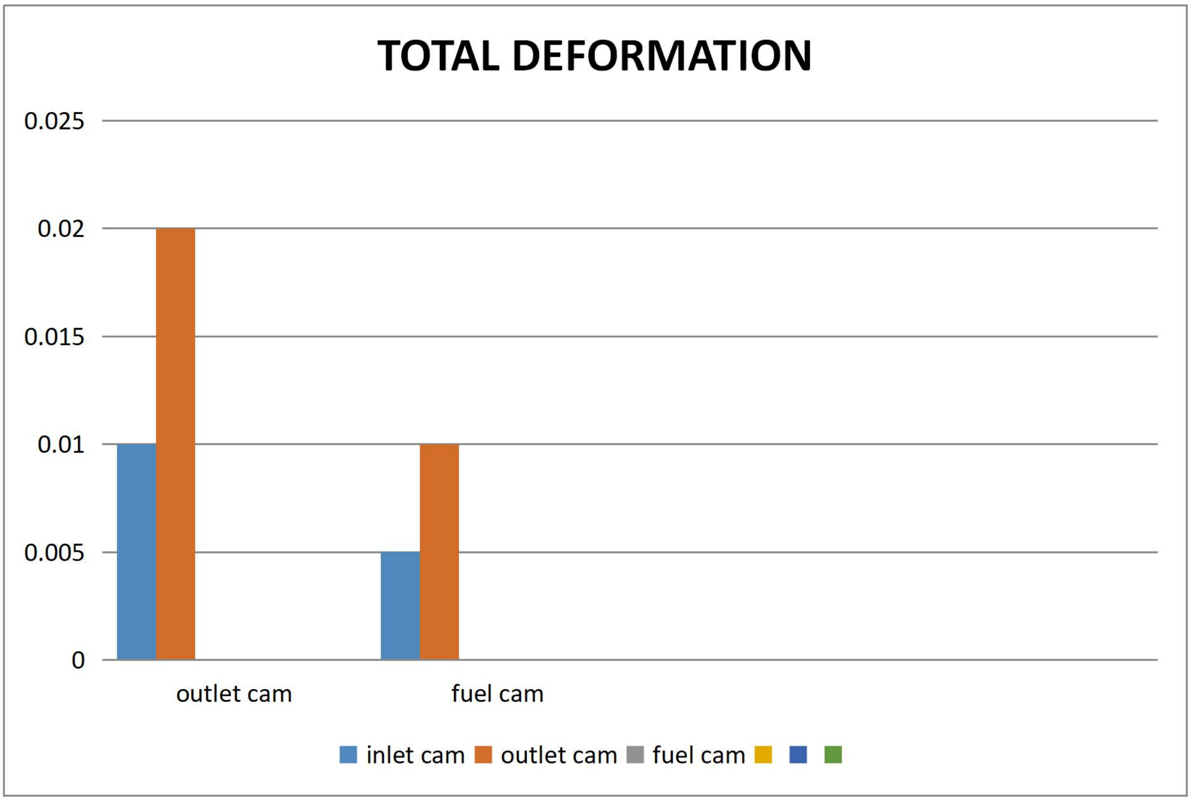
CHAPTER 5

RESULTS AND DISCUSSION

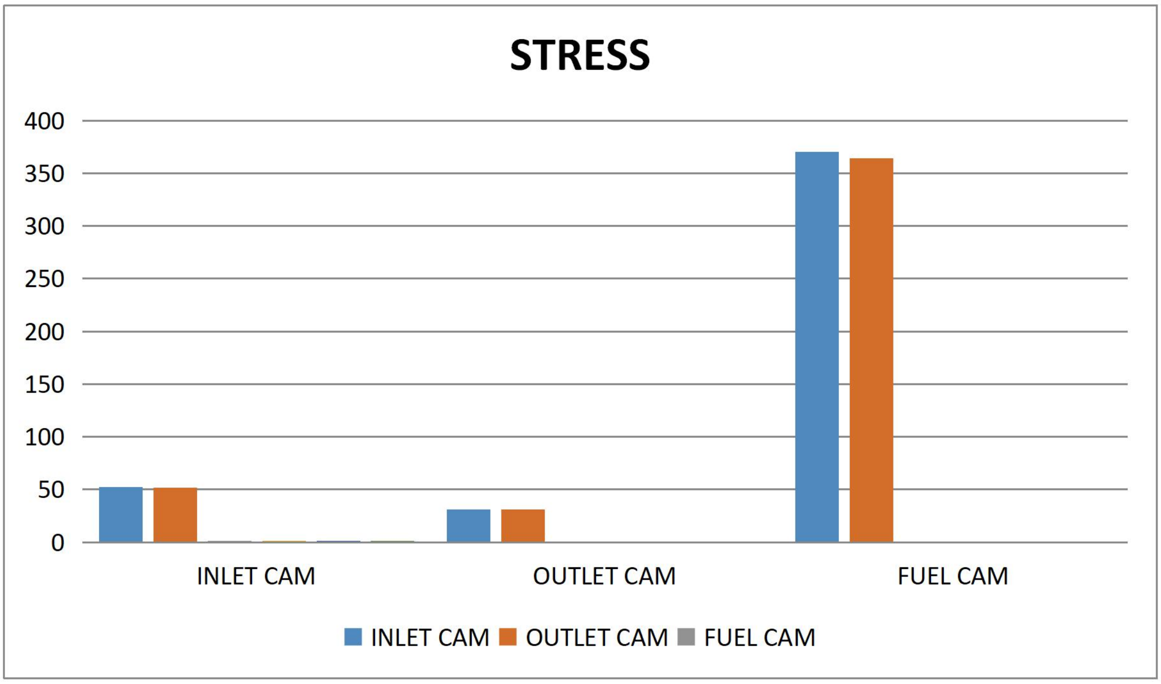
All steps show the procedure for the finite element analysis for diesel engine camshaft. And Table shows the Result of Maximum stress, Maximum strain and total deformation for all three cams on camshaft.

PARAMETERS	**EN 8D**			**CAST IRON**		
	INLET CAM	OUTLET CAM	FUEL CAM	INLET CAM	OUTLET CAM	FUEL CAM
TOTAL deformation(mm)	**0.013**	**0.005**	**0.124**	**0.025**	**0.011**	**0.24**
Von misses equivalent stress(Mpa)	**52.4**	**31.2**	**370.2**	**51.57**	**30.92**	**364.27**
Von misses equivalent strain (mm/mm)	**0.0002**	**0.0001**	**0.0018**	**0.0005**	**0.0003**	**0.0033**

GRAPHICAL ANALYSIS



GRAPHICAL STRESS ANALYSIS



RESULT

In general, steel is a good camshaft material. However, the type of steel has to be matched with the cam follower it runs against, as different grades of steel have different scuff characteristics.

GENERAL DISCUSSION OF CAMSHAFT MATERIAL

This has been a very simplified explanation of camshaft materials, based on over 38 year’s experience. It may assist you to ask the correct questions when purchasing performance camshafts.

CONCLUSION OF CAST CAMSHAFTS

When purchasing a camshaft, enquire which material the camshafts are produced from. A chilled iron camshaft may be more expensive, but its resistance to wear in all conditions, far exceeds any other type of cast iron.

CHAPTER 7

Camshaft Installation

1. We recommend new cam followers be fitted, purchased from us or from a Main Dealer.

2. Check that on full lift on the inlet and exhaust valve spring there is 0.030”/0.75mm clearance between the centre coils of the valve spring. On hydraulic engines a dummy solid cam follower should be used for this purpose.

3. Rotate the engine by hand and ensure that the valves miss the pistons and block by 0.060/1.5mm

4. Don’t over-spring the camshaft. Most modern engines have valve springs that can be used for Phase 1 and 2 camshafts and in some applications Phase 3 cams. So use the lightest spring possible.

5. Before starting the engine, remove spark plugs and spin the engine up until the oil pressure is indicated.

6. Ensure that the cam being fitted is identical to the unit being replaced, except for the cam profiles.

7. Set the camshafts up on the timings supplied on the data sheet. You can change the characteristics of the engine by moving the opening and closing points. This will not have any great effect on the Phase 1and 2 type of cams,

but can make a noticeable difference to the Phase and 5 camshafts, due to the effect on the air wave pulses in the induction and exhaust systems.

The air wave pulses can be affected by induction length/diameter, exhaust length and silencer baffling, so the timing figures we supply are based on experience, but to obtain the maximum power, it may be necessary to adjust the cams to suit the characteristics of the engine. A trip down to your rolling road is the favourite way to obtain the best performance from your engine.

CHAPTER 8

CONCLUSION

We can say that the material EN 8D (Mild Steel) is applicable for the manufacturing of diesel engine camshaft. From the above finite element analysis (static structure analysis) procedure for the diesel engine camshaft results show the values of Maximum stress, Maximum strain and Total deformation.

FUTURE SCOPE:

This Result is applicable for the further analysis as well as for the manufacturing processes can be decided from results. Another application of this analysis is material selection related to camshaft which becomes easier for the manufacturer.

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