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Geometric Modelling And Analysis Of Camshaft Using FEA

[1]Ajay Kumar S, [2]K. Sirisha

[1]Assistant Professor, [2] Assistant Professor

[1]Mechanical Engineering Department,

[1]Mahatma Gandhi Institute of Technology, Hyderabad, India

Abstract: A camshaft is a mechanical rotary element used in IC engines. The crankshaft is responsible for the rotation of the camshaft with the help of various gear trains or idler gear. The main function of the camshaft is to convert the rotary motion of the crankshaft into a reciprocating motion and transfer it to the opening and closing valve in order to supply fuel to the combustion chamber. The performance of the camshaft mainly depends upon the proper design and material used in the camshaft. So, it is very important to select the proper material for the camshaft by which the efficiency of the IC engine can be improved. The material used for automobile camshafts is chilled cast iron and it has comparatively better mechanical properties when compared with similar segment metals. But in this modern world, it's all about competition and more efficiency. In the present work, other two different materials are considered, MMC composite (Al-Sic) and Nitriding Steel-EN40B. There are various materials used for camshafts hence the main aim of the project is to select the perfect material for a camshaft by performing finite element analysis on it. The project is mainly focused on the variation of stress on the camshaft on different materials. A comparison will be made at the end to find the best material for the camshaft. Geometry with the exact dimension of a two-wheeler camshaft is considered and using SolidWorks it is designed, the finite element analysis is carried out using ANSYS maximum stress, and fluctuating load (harmonic loading) is tested for all three materials with respective properties.

***Index Terms* -** Design, Analysis, gear train, idler gear, FEA, reciprocating motion, SolidWorks, CAD, ANSYS, efficiency, IC engines, camshaft.

I. Introduction

A camshaft is a mechanical device used in an IC engine to perform the opening and closing action of the inlet and exhaust valve at the right time. The basic function is to convert rotatory motion into linear motion. As we know, in an internal combustion engine it is very important that the fuel should come into the cylinder at the right time and the exhaust gases should also leave the cylinder at the right moment of time. This function is accomplished with the help of a camshaft.

A camshaft achieves its motion either independently or by the engine crankshaft. Therefore, it is very important to analyze the component that includes the mathematical behaviour and model of the physical model.

The camshaft is driven by the engine's crankshaft through a series of gears called idler gears and timing gears. The gears allow the rotation of the camshaft to correspond or be in time with, the rotation of the crankshaft and thereby allows the valve opening, valve closing, and injection of fuel to be timed to occur at precise intervals in the piston's travel. To increase the flexibility in timing the valve opening, valve closing, and injection of fuel, and to increase power or to reduce cost, an engine may have one or more camshafts. Typically, in a medium to large V-type engine, each bank will have one or more camshafts per head. In the larger engines, the intake valves, exhaust valves, and fuel injectors may share a common camshaft or have independent camshafts. Depending on the type and make of the engine, the location of the camshaft or shafts varies. The camshaft(s) in an in-line engine is usually found either in the head of the engine or in the top of the block running down one side of the cylinder bank. When the piston travels below the level of the ports, the ports are "opened" and fresh air or exhaust gases can enter or leave, depending on the type of port. The ports are then "closed" when the piston travels back above the level of the ports. Valves are mechanically opened and closed to admit or exhaust the gasses as needed. The valves are in the head casting of the engine. The point at which the valve seats against the head is called the valve seat. Most medium-sized diesel engines have either intake valves or exhaust valves or both intake and exhaust valves.

In this case, introduction of two mass, single degree of freedom and multiple degree of freedom dynamic models of cam follower systems are studied.

1.1. Classification

On the basis of lifters used by the camshaft

1. Flat Tappet Cam

Flat tappet cams consist of lifters that are flat shaped and have a slight crown on the face. The lobe of flat tappet cams is constructed in a slightly tapered shape. The tappet rides against the lobes of the camshaft. The tapered shape of the lobes helps the follower or the lifter to spin as it rides on the lobe. The flat tappet can be either a solid flat tappet or a hydraulic flat tappet. Flat tappet cams are generally made up of tool steel, hence they are light in weight and more durable than other types of camshafts.

2. Roller Cam

The roller cams comprise a wheel and axle arrangement. The wheel is attached to the base of the lifter body and is supported by needle bearings. The lobes of the roller camshafts are flat in shape. The roller camshafts are linked to each other so as to prevent them from rotating or spinning. Roller cams are advantageous because they reduce friction, thereby causing a significant increase in power. Also, the wear and tear rate of such cams are quite low. The engine efficiency can also be increased with the help of roller camshafts because it causes the valves to open at a faster rate and stay open for a longer duration, thereby allowing a proper intake and exhaust of fuel and air.

On the basis of the shape of the driver member of the camshaft

1. Disk or Plate Cam

A disk or a plate cam is also known as a radial cam. It consists of an irregular contour plate that is used to transfer motion to the driven member or the follower. The axis of the disk cam is perpendicular to the direction of motion of the follower.

2. Cylindrical Cam

A cylindrical cam is also known as a barrel of drum cam. As the name itself suggests, this type of cam is shaped like a cylinder. There exists a groove cut on the cylindrical cam surface. The follower tends to follow the groove path for movement. The axis of a cylindrical cam is parallel to the direction of motion of the driven member.

3. Translating Cam

The translating cam has a grooved contour plate. The follower or the driven member oscillates along the face of the cam grooving.

4. Wedge Cam

The structure of a wedge cam is wide at the base and has a pointed end. The follower tends to exhibit a sliding motion against the cam.

5. Spiral Cam

A spiral cam is a spiral semi-circular contour that has a groove on its face. The follower exhibits a vertical motion with respect to the reciprocating motion of the driver member of the camshaft or the cam.

6. Heart-shaped Cam

The structure of a heart-shaped cam is an asymmetrical heart. The follower moves along the edge of the cam. The motion exhibited by a heart-shaped cam is uniform and continuous. It is mainly used to evenly wound the wire in the form of a solenoid.

7. Spherical Cam

The spherical cam is shaped like a sphere that consists of a groove on its curved surface. The driven mechanism or the follower moves on the grooving. The movement of the follower is perpendicular to the axis of rotation of the spherical cam.

8. Conjugate Cam

A conjugate cam is provided with two rollers. Both the rollers are connected to the follower. The rollers tend to constrain the motion of each other, thereby eliminating noise. Such types of cams are used in applications where little, or no noise is tolerable.

9. Globoid Cam

The structure of a globoid cam is similar to that of a cylindrical cam. The only difference, here, is that the shape of the cylindrical shape is replaced by a convex or concave structure. The follower tends to move along the fulcrum.

Camshaft Configurations

There are several arrangements of camshafts on engines out of which the following three configurations are most commonly used:

1. Single Overhead Cam

A single overhead cam represents the configuration in which the engine contains one cam per head. This means that an inline 4 cylinder or inline 6-cylinder engine consists of a single cam, while the V-6 and V-8 engines have two cams, one for each head. The cam tends to transfer motion to the rocker arms, which in turn presses down on the valves causing them to open. The closed position of the valve is achieved with the help of a spring that is attached to the rocker arms on one end and to the valve at the other end.

2. Double Overhead Cam

A double overhead configuration of cams represents an engine that has two cams per head. This means that the inline engines have two cams, while V engines have four. The engines that contain four or more valves per cylinder prefer to use a double overhead cam configuration. A double overhead cam increases the intake and exhaust capacity of the valves by expanding space for the gases and fuel to flow. This in turn increases the engine power. A single overhead cam used for an engine that contains two or more valves is unable to transfer motion to all the valves properly, hence it is not usually preferred.

3. Pushrod

The camshaft of a pushrod engine is not present on the head, but instead, it is present inside the engine block. Such an engine makes use of long rods that go through the block into the head. The camshaft is driven with the help of gears or short chains. The function of the camshaft here is to transfer mechanical motion into the rods, which in turn moves the rockers. The rockers open and close the valve accordingly. The long rods tend to add mass to the system, thereby increasing the load on the valves and decreasing the speed of pushrod engines. Hence, the pushrod configuration of a camshaft is used in applications where a limited speed of the engine is desired.

1.2. Advantages of camshaft:

The following advantages are:

- ✓ Camshaft enables proper inflow and outflow of fuel and exhaust gases respectively.
- ✓ The design is quite simple.
- ✓ It is durable and easy to maintain.
- ✓ Provides smooth operation even at high speed.
- ✓ A single camshaft can be used for many cylinders.

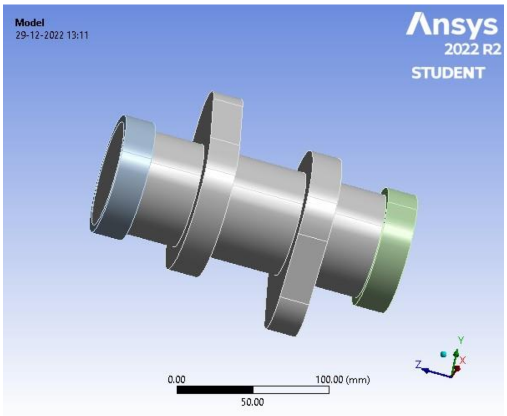
1.3. Applications of camshaft:

- The camshaft is the rotating part of the engine cylinder. They are mainly employed to convert rotary motion into reciprocating motion.
- In the I.C engine, the camshaft is employed to operate the intake and exhaust gas from the poppet valve, which is mechanically controlled by the ignition system and electric motor.
- Sometimes the camshaft also operates as rocker arms to move the exhaust valve from the back of the cam that is 180 degrees with the inlet valve.

II. GEOMETRIC MODELLING OF CAMSHAFT

Camshaft is the one which converts rotary motion to linear motion, which plays an important role in combustion of 4stroke engine. ANSYS software is used in this work to mesh (finite element modeling) and simulate the stress-stain distribution in the camshaft. Three materials are considered for the material optimization of the camshaft, Chilled Cast iron which is existing Camshaft material is Compared with the similar mechanical properties' elements like MMC composite (Al-Sic) and Nitriding Steel-EN40B.

2.1 Model of camshaft



2.2 Mechanical properties of materials:

2.2.1.Chilled Cast Iron

Young's modulus	190000 MPa
Poisson's ratio	0.27
Bulk modulus	158330 MPa
Shear modulus	74803 MPa
Density	7300 kg/m^3
Tensile Strength	41306 MPa
Compressive strength	140 MPa
Yield Strength	275.7 Mpa
Thermal expansion coefficient	3.24/KMPa
Thermal conductivity	47 W(m-K)
Specific heat	510 J/(Kg-K)

2.2.2. MMC Composite(Al-SiC)

Young's modulus	167000 MPa
Poisson's ratio	0.3
Bulk modulus	139170 MPa
Shear modulus	64210 MPa
Density	3100 Kg/m^3
Tensile Strength	220 MPa
Compressive strength	118 MPa
Yield Strength	140 MPa
Thermal expansion coefficient	0.22/K
Thermal conductivity	180 W(m-K)
Specific heat	808 J/Kg-K

2.2.3. Nitriding Steel(EN-40B)

Young's modulus	248000 MPa
Poisson's ratio	0.31
Bulk modulus	136000 MPa
Shear modulus	10000 MPa
Density	7.19 gm/cm^3
Tensile Strength	413 MPa
Compressive strength	185 MPa
Yield Strength	362 MPa
Thermal expansion coefficient	0.62/K
Thermal conductivity	69.1 W/m-K
Specific heat	502 j/kg-K

2.2 FEA analysis

ANSYS is known for the standard in the discipline of CAE. A variety of tasks can be performed beginning from FEA to finish the product optimization analysis using ANSYS. The finite element method is a powerful tool that could help to obtain the numerical solution of a considerable variety of engineering problems as well as mathematical physics problems. In this technique, the area wherein the evaluation is to be achieved is divided into smaller bodies or units called as finite elements. A finite element approach is a flexible tool that is used in numerous industries to resolve numerous realistic engineering problems. The results within the FEA evaluation are depicted using the system within the shape of a color sample, as an instance the pressure distribution in any project, vibrational properties, and so on.

Analytical procedure

The steps involved in the analytical procedure are given below:

2.2.1. Planning of analysis

This is seemingly the most critical piece of any investigation as it aids guarantee the achievement of the undertaking. The principal motive behind a FE examination is to model the behavior of a structure below an arrangement of loads. Planning of analysis offers with the extent of the results accuracy as higher would be the making plans, more correct will be the results.

2.2.2. Pre-Processor

This is a program that processes the input information to provide the output that is used as input to the subsequent phase (solution). Here ANSYS workbench is used as a Pre-Processor. The input data might be pre-processed for the output data and the preprocessor will generate the statistics files automatically with the help of users that will be used by the solution.

2.2.3. Creating the model

The model is sketched in the 2 D sketch space with the proper units and then it is transformed into the 3 D space with the help of SolidWorks. It is then imported to ANSYS through neutral report formats like IGES, STL.

2.2.4. Applying a mesh

In FEA One of the critical steps is meshing. Meshing is used to divide a large model into some of the discrete elements called the meshing elements. Meshing is done because it is so easy to calculate the problem for a small element than bulk material. Therefore, the finer the mesh, better are the consequences, but it also takes a long time to calculate the outcomes.

2.2.5. Assigning properties

Material properties like Poisson's ratio, density, Young's Modulus, and if relevant coefficients of thermal expansion, friction, thermal conductivity, damping effect, specific heat, etc. will have to be defined.

2.2.6. Apply loads (Input parameters)

This step is so important for the evaluation because it defines the boundary for the consequences of the problem. All the loads on the models and the boundary conditions need to be implemented at the precise places for the exact solutions to the problem.

2.2.7. Apply boundary conditions.

The boundary condition includes different loads, supports, restrictions, and any other condition required for the complete evaluation. Special care is required for assigning loads and restrictions to the components. Making use of the right boundary condition is vital for the precise arrangement of the design problem.

2.2.8. Solution

The solution phase is completely automatic. The Finite Element solver can be split into three fundamental elements, the preprocessor, the mathematical engine, & the post-processor. The pre-processor peruses in the model made through the preprocessor and defines the scientific representation of the model. Every effect is dispatched to an outcome record, which may be perused by the post-processor.

2.2.9. Post-Processor

This step specifies the effects of the problem. It is a convenient processing program that uses interactive color graphics. It has great plotting characteristics for indicating the results received from the FEA. The outcomes obtained from the analysis can be displayed in seconds, which may take an engineer hour to evaluate from a numerical output. The post-processor phase is automatic and generates the graphical output in the form specified by the user. Since the graphical output offers detailed information about the required result data. In this problem, the post-processor used are Result Viewer and Plot result.

III. PROBLEM STATEMENT

The Cam Shaft which is used in the automobile will be usually made of the metal (Chilled cast iron with 1% chrome), as the metals have greater weight and have lesser wear resistance and due to which it might get corroded, loose its strength, wear out very soon, and we know metal has higher rate of stress strain deformation. So Composite material, MMC composite(Al-SiC) and Nitriding steel(EN40B) are selected as a replacement and analysed to check whether it can be replaced with existing metals used in Automobiles. As composite materials have high strength to weight ratio, higher wear resistance has more advantages when compared to metals.

IV. RESULTS AND DISCUSSION

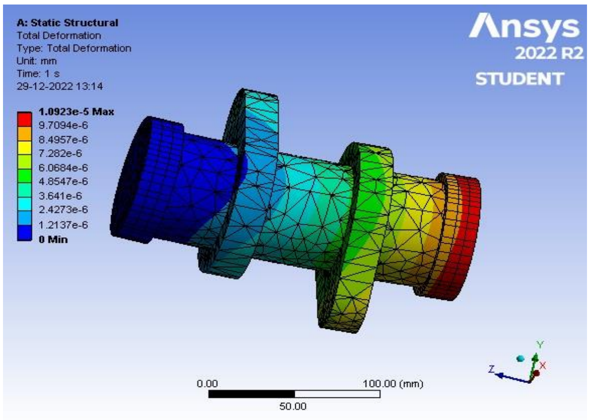
The FEA results of the camshaft have been analyzed by using different materials and compared them with the available results for validation. These evaluations are important to understand which material can display better results than the prevailing materials used for making the camshaft.

4.1 Static structural analysis

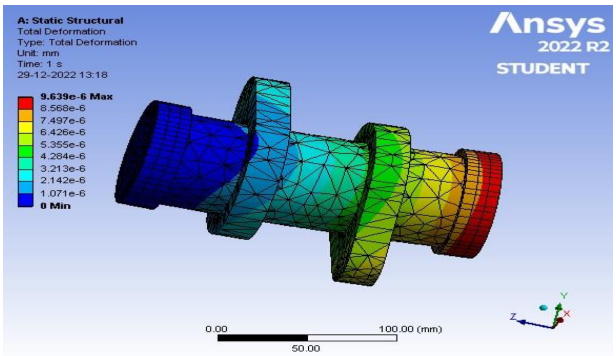
The static structural analysis is executed by applying different materials and the total deformation, stress(von-mises), strain in the camshaft for a moment of 150N-m are done and the camshaft is fixed at one end.

4.2 TOTAL DEFORMATION

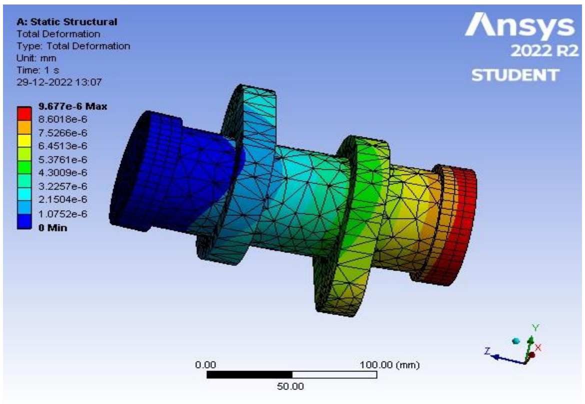
The results obtained in ANSYS are.



Total deformation in Al-SiC composite material

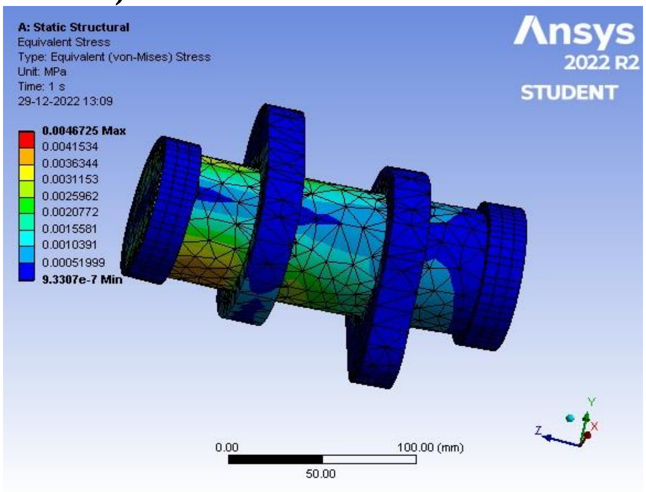


Total deformation in Nitriding steel

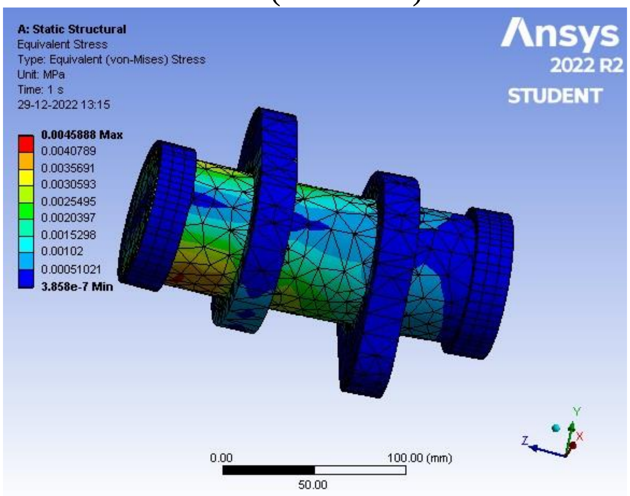


Total deformation in Chilled cast iron

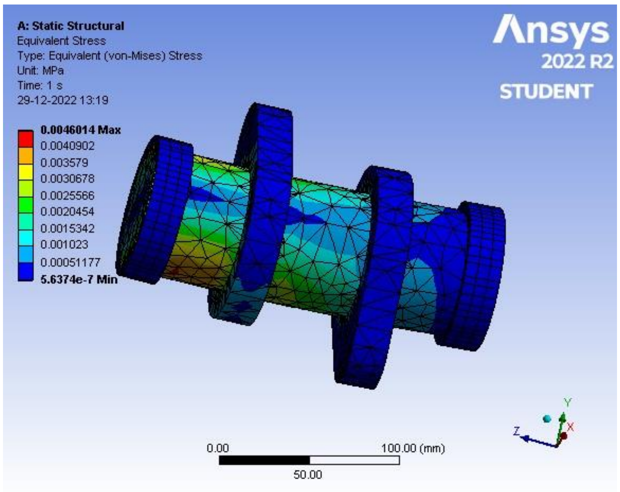
4.3 TOTAL STRESS (VON-MISES) RESULTS



Total stress(von-mises) for chilled cast iron

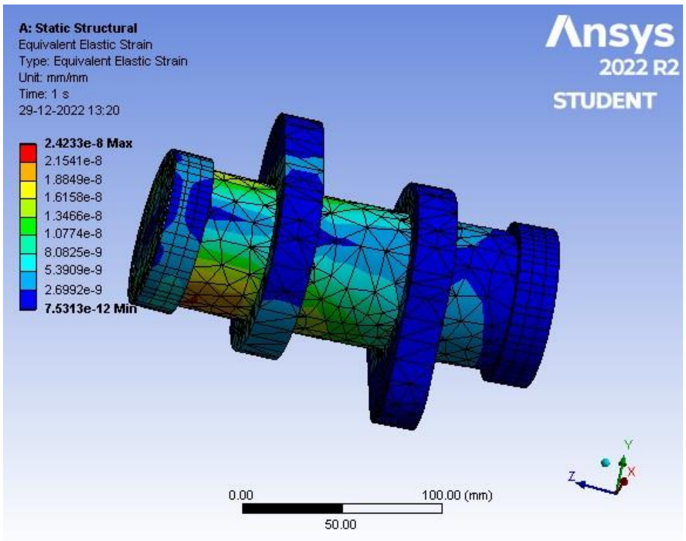


Total stress (von-mises) for Al-SiC composite material

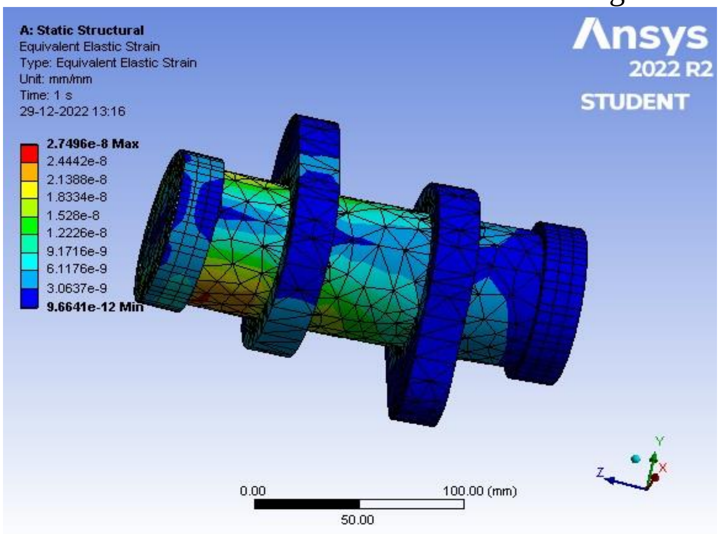


Total stress for nitriding steel

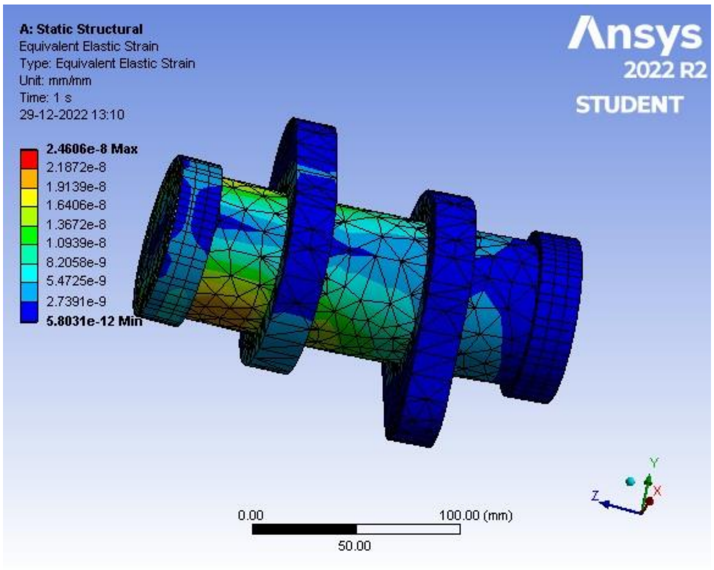
4.4 TOTAL STRAIN RESULTS



Total strain for nitriding steel



Total strain for Al-SiC composite material



Total strain results for Chilled cast iron

4.5 Comparision of material considered

Material	Maximum deformation(mm)	Maximum stress(MPa)	Maximum strain(mm/mm)
Chilled Cast Iron	9.677e-6	0.0046725	2.4606e-8
Nitriding Steel	9.639e-5	0.0046014	2.4233e-8
Al-SiC	9.0293e-5	0.0045888	2.7496e-8

V. CONCLUSIONS

Comparing the above results,

- The minimum deformation occurs in chilled cast iron when compared with nitriding steel and Al-SiC composite material.(chilled cast iron < Al-SiC composite < nitriding steel).
- The minimum stress obtained in Al-SiC composite when compared with other two materials.(Al-SiC < nitriding steel < chilled cast iron).
- The minimum strain is obtained in nitriding steel when compared with other two materials. The strain developed in nitriding steel and chilled cast iron are not of that different. Even cost also plays an important role in selecting material. When we compare the three materials chilled cast iron is of less cost .
- For manufacturing the camshaft, Chilled cast iron > nitriding steel > Al-SiC composite.

REFERENCES

[1] G.K. Matthew., D. Tesar. (1976), Cam system design: The dynamic synthesis and analysis of the one degree of freedom model, Mechanism and Machine Theory, Volume 11, Issue 4, Pages 247-257. K. Elissa, “Title of paper if known,” unpublished.

[2] M.O.M Osman., B.M Bahgat., Mohsen Osman., (1987), Dynamic analysis of a cam mechanism with bearing clearances, Mechanism and Machine Theory, Volume 22, Issue 4, Pages 303-314.

[3] Mahesh R. Mali, Prabhakar D. Maskar, Shravan H. Gawande, Jay S. Bagi, “Design Optimization of Cam & Follower Mechanism of an Internal Combustion Engine for Improving the Engine Efficiency”, Modern Mechanical Engineering, 2012, Issue 2, pp.114-119.

[4] Yuan L. Lai, Jui P. Hung, and Jian H. Chen, “Roller Guide Design and Manufacturing for Spatial Cylindrical Cams”, World Academy of Science, Engineering and Technology, Vol:2 2008-02-29.

[5] Per Lindholm, Stefan Björklund, Miguel Calvo Cortes, “Characterization of wear on a cam follower systemin a diesel engine”, Wear, 254 (2003), pp 1199–1207.