Dynamic Analysis of a cylindrical cam and Follower using Finite Element Analysis

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Abstract: *The cylindrical cam and follower mechanism is highly used in the packaging industry to obtain the sequential operation of material filling in the packaging machine. The occurrence of frictional wear between the cam and follower involves the reduction of cam life that eventually affects the quality of packing in package industry. In this work, an attempt is made to simulate the static and dynamic analysis of cam at low speed. Both the static and dynamic simulations are made for the cylindrical cam follower arrangement using a commercially available finite element code ANSYS 14.5. The simulation of static analysis is carried out to predict the deformation of cam. The simulation of dynamic analysis is also conducted to investigate the effect of vibration on the performance of cam follower mechanism during a packing operation.*

Keywords*: Follower & Cam; Point Contact; Vibration Analysis; Finite Element Approach.*

1. Introduction

Cam and follower mechanism is preferred over a wide variety of Packaging machine because due to the cam and follower it is possible to obtain an unlimited variety of motions. Again the cam and follower has a very important function in the operation of many classes of machines, especially those of the automatic type, such as printing presses, shoe machinery, textile machinery, gear-cutting machines, screw machines etc. The cam may be defined as a machine element having a curved outline or a curved groove, which, by its oscillation or rotation motion, gives a predetermined specified motion to another element called the follower. In other word, cam mechanism transforms a rotational or oscillating motion to a translating or linear motion. In fact, cam can be used to obtain unusual or irregular motion that would be difficult to obtain from other linkage. The variety of different types of cam and follower systems that one can choose from is quite broad which depends on the shape of contacting surface of the cam and the profile of the follower. In this work an attempt is made to study the static and dynamic analysis of cam at low speed. In static analysis to study the deflection of cam and follower with respect to angular velocity and in dynamic analysis to calculate natural frequency with respect to given loading condition. The modeling of Cam and follower is done on CATIA V5 Software and analysis of Cam and Follower is done by using ANSYS14.5Software

2. Project Background

Cam is an element of the cam-follower mechanical system that compels the Movement of the follower by direct contact. Cam is a mechanical component that translates movement from circular to reciprocating by using mating follower [1]. A cam can be defined as a device that having a curved outline or a curved groove that usually called as cam profile. A common example is the camshaft of 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 [3]. The cam mechanism may be modeled as a three mass system (leading element, cam and follower) with three degrees of freedom (displacement of the leading element, cam and follower). Due to complexity of such a model, usually, the mechanism is divided into two systems leading element camshaft cam system and cam follower system which are considered as one degree of freedom systems. The motion of the follower is the result of the program. Just as a computer program, so is a cam. Thus, the system can be thought of as a mechanical information device. Accordingly, the goals of the designer is to build a program, establish the locus of the contact point between the cam and follower, produce the cam profile coordinate system, and fabricate the cam within an acceptable accuracy. [1,2] After all the parts are assembled the performance of the cam-follower system is observed There are three types of cam followers, and each type of the follower influences the profile of the cam. The three types are the knife-edge, the roller follower and the flat face follower. The follower restraint to the cam is positive-driven by the use of rollers in the cam groove or multiple conjugate cams, is spring-loaded, or occurs by gravity.

3. Problem statement

One of the many potential problems with unwanted vibrations in high-speed Machinery is the possible introduction of follower jump in a cam-follower Mechanism. Jump is a situation where the cam and follower physically separate. [8] When they come back together the impact introduces large forces and thus large stresses, which can cause both vibrations and early failure of the mechanism [5]. Many companies are now conducting in depth vibration analyses on their existing machines and redesigning many stations to reduce the overall vibrations in the machine. [6]

4. Objective

Study and analysis the vibration factor simulation analysis the effect using ANSYS 14.5 of impact force on vibration in cam follower system [7]

5. Scope

A study was conducted to find the optimum equation of motion for the system from the dynamic model. The equation relates the cam displacement, velocity and acceleration to analyze and prove the vibration system of cam follower. [10] The velocity, acceleration and displacement also involved to investigate the optimum force to the cam system on vibration in high speed rotation per minute (RPM) [4].

6. Modal Analysis

Modal analysis of roller follower is performed by Ansys software to determine the vibrations characteristics such as natural frequencies and mode shapes [9].

7. Solid Modeling of Cam

To perform finite element analysis of roller follower, the solid model of the same is essential. **Figure 1** shows a solid model of cylindrical cam

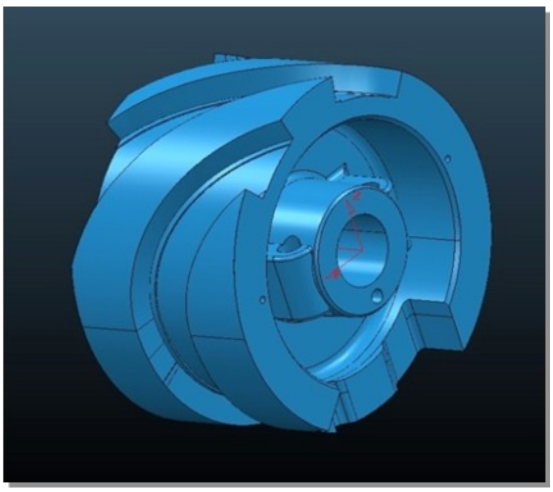


Figure 1.Solid model of cylindrical cam

8. Connections and Contacts of Cam and Follower

To perform finite element analysis of cylindrical cam and follower, **Figure2** shows Connections and Contacts of Cylindrical Cam and Follower

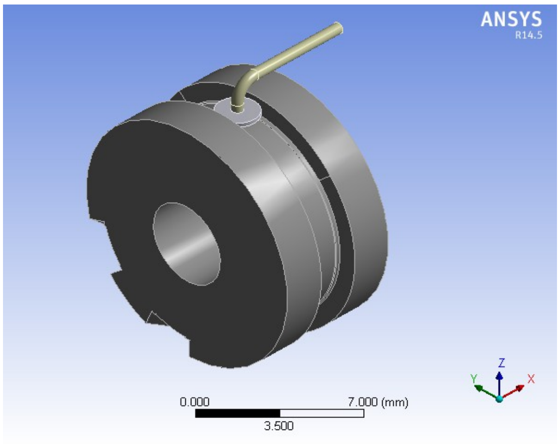


Figure 2 Connections and Contacts of Cylindrical Cam and Follower

According to connecting the cam and follower on both the static stress factor is analysed by only Cam because of the maximum friction occur and wear forming is builded maximum level in cam object the cam is fixed element and follower is moving element through the axes of the cam and moving the profile grove of the cam. So the static stress factor is analysed and following by meshing and nodes given below.

8.1. Objects Name

Contacts and joints

State: Fully defined

Contact type: Contact and joints

Scoping methods: Geometry selection

Geometry: All bodies

Tolerance type: Slider

Tolerance slider level: 0

Tolerance value: 4.988e-002mm

8.2. Objects Name

Contact Region Frictionless Part 1and Part 3

Contact: 1 face

Target: 1 face; 2 faces

Target bodies: Both

8.3. Meshing

Physical Preference: Mechanical

Total Nodes: 13029

Elements : 6653

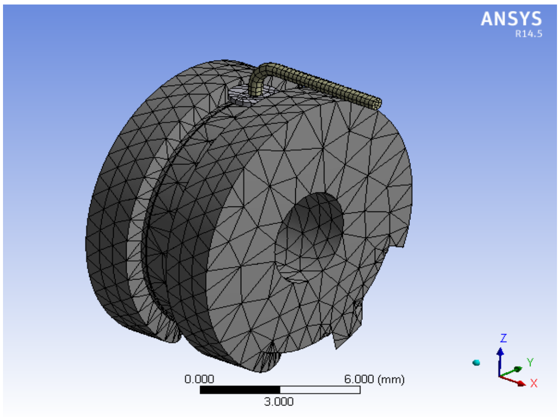


Figure 3. Meshing

8.4. Boundary Conditions

Part A: Cylindrical support – 0mm

Part B: Frictional Pressure --1000N

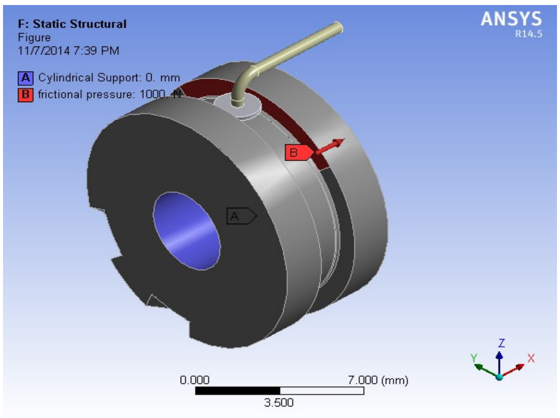


Figure 4. Boundary Conditions

8.5. Results (Von-mises Stress)

The given frictional pressure 1000N in part B the total deformation occurs time level 0 to1 hour that shows 0.0042905mm is maximum level to achieve deformation

	Total Deformation	Equivalent Stress
Minimum Part A	0 mm	0Mpa
Maximum Part B	4.2905e-003mm	290.17Pa

Table 1

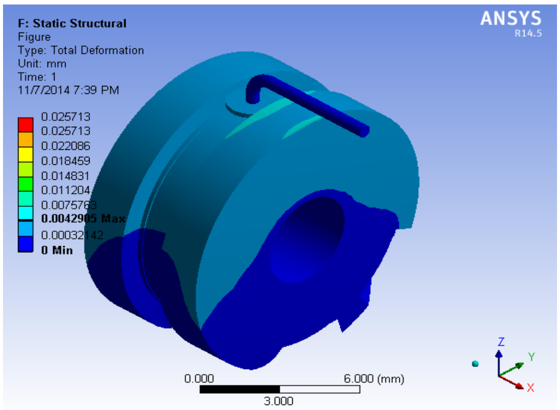


Figure 5.Total Deformation

8.6. Equivalent (Von-mises Stress)

The given frictional pressure 1000N in part B. In equivalent von-mises stress level is occurring0 to 290.17Mpa is maximum along with X – axis.

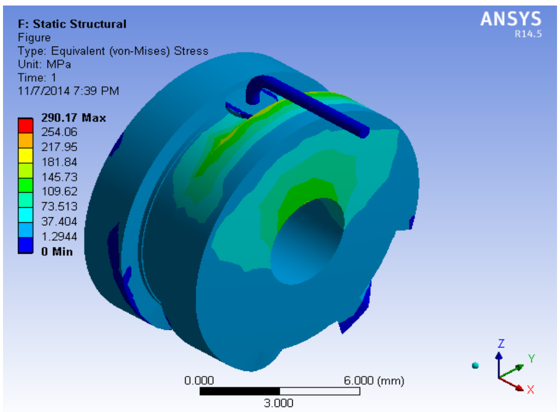


Figure 6.Equivalent von-mises stress

8.7. Design Life

Initially 1.e009cycles

8.8. Life cycle Results

Minimum : 7293.2 cycles

Maximum: 1.3711e005

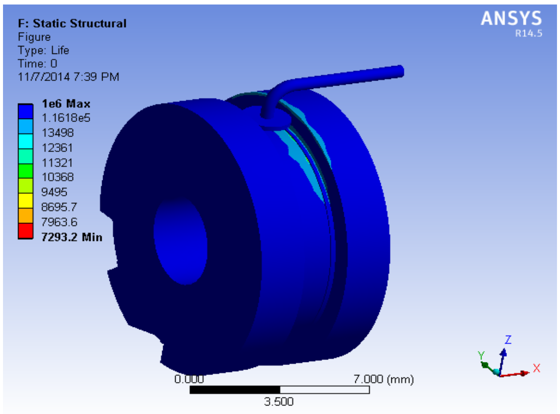


Figure 7. Life

9. Analysis

9.1. Vibration analysis

9.1.1. Statistics

Nodes: 10676

Elements: 6193

9.2. Modal Analysis (ω) Natural Frequency Free body vibration

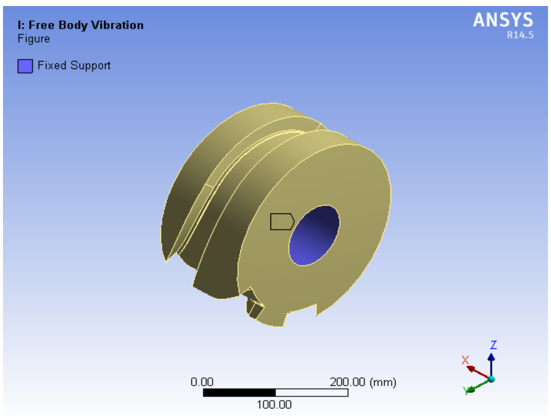
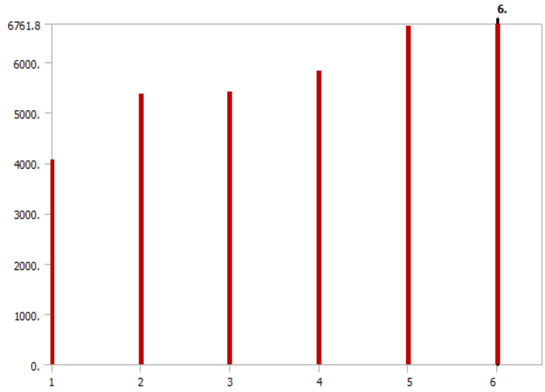


Figure 8. Free body Vibration



Graph1. Modes and Frequency level

The amplitude level is occurs the Natural frequency stage the total six modes and frequency levels are shown below

Mode	Frequency (Hz)
1	4072.4
2	5375.8
3	5413.7
4	5821.7
5	6727.3
6	6761.8

Table 2. Details

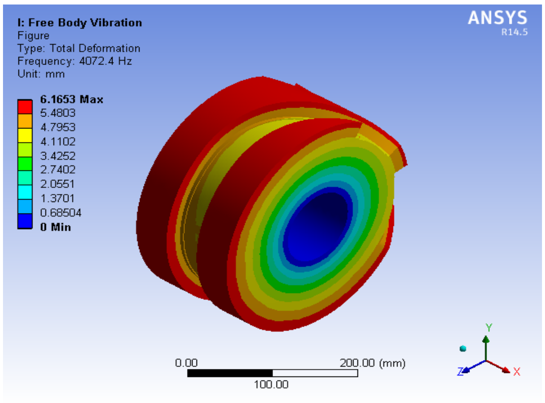


Figure 9. Nodal displacement solution 1st frequency (4072.4 Hz)

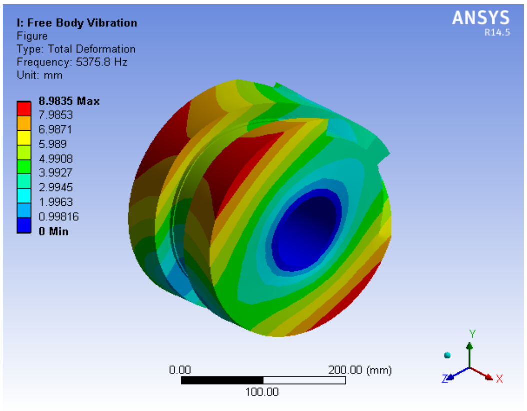


Figure 10. Nodal displacement solution 2nd frequency (5375.8 Hz)

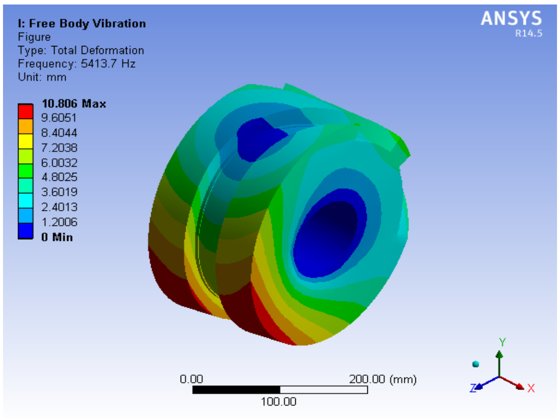


Figure 11. Nodal displacement solution 3frequency (5413.7 Hz)

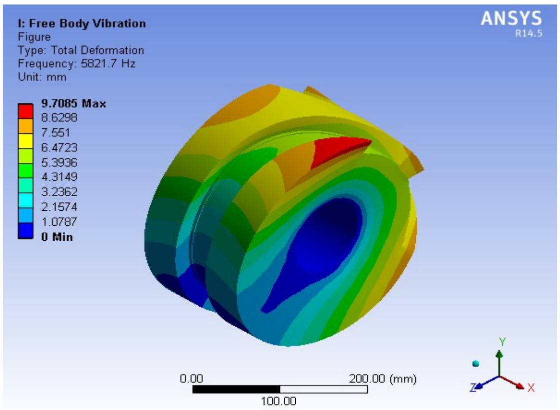


Figure 12.Nodal displacement solution 4th frequency (5821.7 Hz)

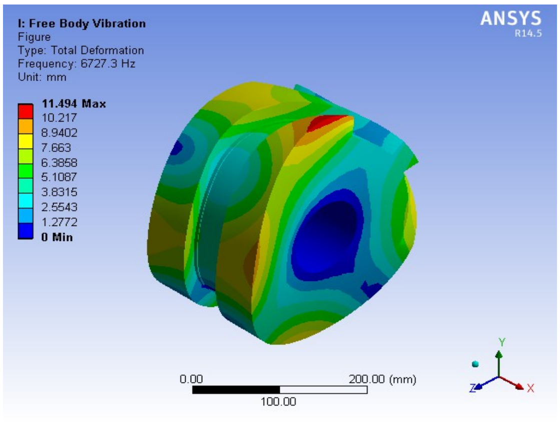


Figure 13.Nodal displacement solution 5th frequency (6727.3 Hz)

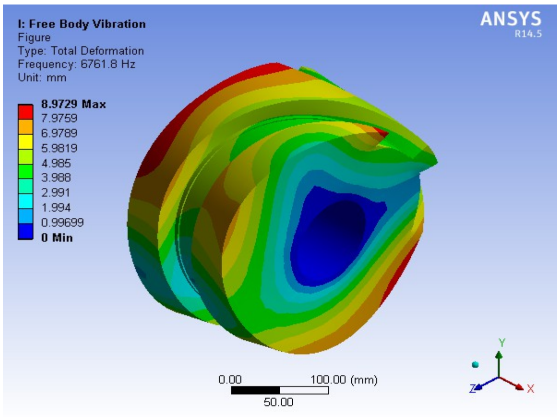


Figure14. Nodal displacement solution 6th frequency (6761.8Hz)

Figure 9 shows the modal analysis at the 4072.4 Hz frequency and element behavior. Red colour zone indicates the deformation of cam having range from 5.4803mm [min.] to 6.1653 mm [max.]. Blue colour zone indicates the deformation cam having range from 0 mm [min.] to 0.68504 mm [max.].

Figure 10 shows the modal analysis at the 5375.8 Hz frequency and element behavior. Red colour zone indicates the deformation of cam having range from 7.9853mm [min.] to 8.9835 mm [max.]. Blue colour zone indicates the deformation cam having range from 0mm [min.] to 0.99816mm [max.].

Figure 11 shows the modal analysis at the 5413.7Hz frequency and element behavior. Red colour zone indicates the deformation of cam having range from 9.6051mm [min.] to10.806mm [max.]. Blue colour zone indicates the deformation cam having range from 0 mm [min.] to 1.2006mm [max.].

Figure 12 shows the modal analysis at the5821.7 Hz frequency and element behavior. Red colour zone indicates the deformation of cam having range from 8.6298mm [min.] to 9.7085mm [max.]. Blue colour zone indicates the deformation cam having range from 0 mm [min.] to 1.0787mm [max.].

Figure 13 shows the modal analysis at the 6727.3Hz frequency and element behavior. Red colour zone indicates the deformation of cam having range from 10.217mm [min.] to 11.494mm [max.]. Blue colour zone indicates the deformation cam having range from 0 mm [min.] to 1.2772mm [max.].

Figure 14 shows the modal analysis at the 6761.8Hz frequency and element behavior. Red colour zone indicates the deformation of cam having range from 7.9759mm [min.] to 8.9729mm [max.]. Blue colour zone indicates the deformation cam having range from 0 mm [min.] to 0.99699mm [max.].

10. Harmonic response

10.1. Forced Body Vibration

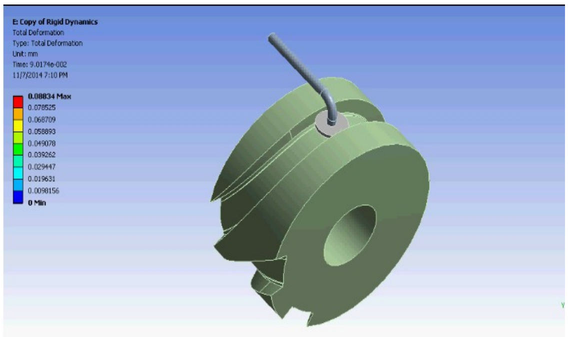


Figure15. Forced body Vibration Total Deformation

Here the extreme time level 0.18509min is to be selected for analysing the total Deformation level is achieved 0.8837mm as shown in fig 15

Definition: The directional deformation under

X-axis, Y-axis, Z-axis

Minimum frequency: 0Hz

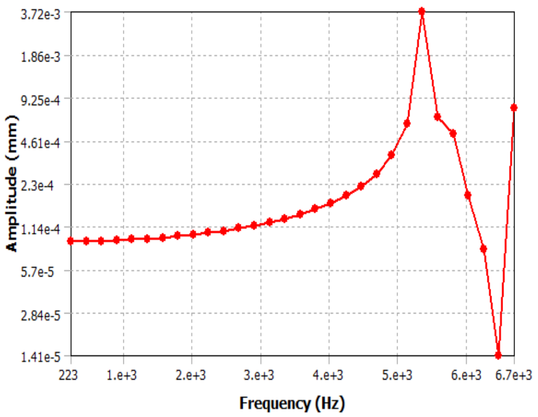
Maximum frequency: 6700Hz

10.2. Results

	X-axis	Y-axis	Z-axis
Maximum amplitude	3.7249e-003mm	2.7048e-004mm	2.4898e-004mm
Frequency		5360Hz	
Real	3.7249e-003mm	-2.7048e-004mm	-2.4898e-004mm

Table 3.Results found in three axis

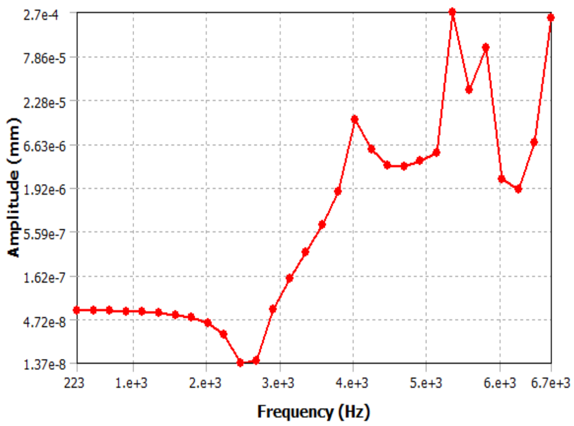
10.3. Frequency response in X- axis



Graph 2.Frequency vs. Amplitude

The above graph represents the Frequency level in X-axis is 5360Hz the same Amplitude is 3.7249e-003mm.

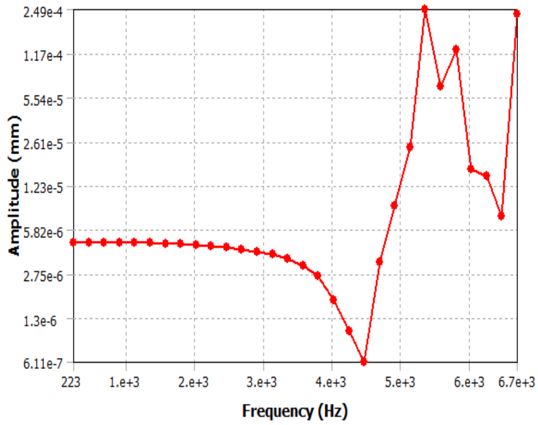
10.4. Frequency response in Y- axis



Graph 3.Frequency vs. Amplitude

The above graph represents the Frequency level in Y-axis is 5360Hz the same Amplitude is 2.7048e-004mm

10.5. Frequency response in Z – axis



Graph 4.Frequency vs. Amplitude

The above graph represents the Frequency level in Z-axis is 5360Hz the same
Amplitude is 2.4898e-004mm

11. Material data

11.1. Material Composition EN24 Steel.

The Chemical composition of EN24 is (Equivalent BS 970:1955)

Carbon	0.36-0.44%
Nickel	1.30-1.70%
Molybdenum	0.20-0.35%
Silicon	0.10-0.35%
Manganese	0.40-0.70%
Sulphur	0.040 Max
Phosphorus	0.035 Max

11.2. Structural Steel

Density	: 7.85e-006 kg mm^-3
Coefficient of thermal expansion :	: 1.2e-005 C^-1
Specific Heat	: 4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	: 6.05e-002 W mm^-1 C^-1
Resistivity	: 1.7e-004 ohm mm
Compressive Ultimate Strength	: 0MPa
Compressive Yield Strength	: 250MPa
Tensile Yield Strength	: 250MPa
Tensile Ultimate Strength	: 460MPa
Reference Temperature	: 22°C

11.3. Structural Steel Strain-Life Parameter

Strength Coefficient	: 920 MPa
Ductility Coefficient	: 0.213
Ductility Exponent	: 0.47
Strength Exponent	: 0.106
Cyclic Strain Hardening Exponent	: 0.2
Cyclic Strength Coefficient	: 1000 MPa
Young's Modulus	: 2e5MPa
Relative Permeability	: 10000
Poisson's Ratio	: 0.3
Bulk Modulus MPa	: 2.e+005
Young's Modulus	: 2e5MPa
Relative Permeability	: 10000
Poisson's Ratio	: 0.3
Bulk Modulus MPa	: 2.e+005
Shear Modulus MPa	: 76923

12. CONCLUSIONS

The simulation of static and dynamic analysis are successfully carried out for the cylindrical cam Follower mechanism using ANSYS 14.5. From the study, the life cycle of the cam is found for the EN24 structural steel material. The maximum deflection and the ultimate life cycle of the cam are found as 0.004 mm and 1.37e5 cycles. The maximum deformation occurs in a cam when the cam operates at its fifth mode for the designed load condition. Therefore, there is a need for search of a suitable material, which can offer a higher life cycle when the cam vibrates at higher frequencies with dynamic load condition.

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