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MODELING AND STRUCTURAL ANALYSIS OF A CAM SHAFT

[1] DR.T.PRASAD, [2] CH RAVITEJA, [3] D NITHIN KUMAR, [4] J JITHENDER, [5] N UDAY KIRAN, [6] R BHOOPATHI

[1]Assistant Professor, Dept. Of MECH, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad,

[2,3,4,5,6]BTech Student, Dept. Of MECH, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad

Abstract: *The idea of harnessing combustion to perform mechanical work is by no means a new one. The internal combustion engine, as we know it today, has its origins in the last century, however the idea for controlling combustion to perform mechanical work dates back to the Renaissance. Even with the advent of alternative sources of power for commerce and personal applications, the internal combustion engine represents a large portion of the power generation available in this country. There are numerous types of internal combustion engines, each with a variety of subsystems. Automotive cams can be manufactured as copied or original parts. Copied parts are typically produced on a rocker type cam grinder and the original parts are produced on a computer numerical control grinder. Therefore, various errors associated with these manufacturing techniques are studied herein. Installing cams with profile errors in an engine may result in the dynamic malfunction of its valve train. In order to study the effect of these profile errors, some of the error cam profiles that were predicted for the rocker grinder were manufactured and tested in an actual valve train. In addition, the effects of error cam profiles were investigated by using an existing valve train simulation model. In automobile and tractor engines, the camshafts (or cam lobes) are made of* ***chilled cast iron****, which is comparable to the alloyed steels used in the manufacture of bearings. The wear resistance of chilled cast iron is considerably higher of that of ductile cast iron. It was found by both experimentation and simulation that camshaft errors on the order of typical shop tolerances had little impact on the dynamics of high speed valve trains.*

I. INTRODUCTION

Since the origination of the automobile, the internal combustion engine has evolved considerably. However, one constant has remained throughout the decades of ICE development. The camshaft has been the primary means of controlling the valve actuation and timing, and therefore, influencing the overall performance of the vehicle. The camshaft is attached to the crankshaft of an ICE and rotates relative to the rotation of the crankshaft. Therefore, as the vehicle increases is velocity, the crankshaft must turn more quickly, and ultimately the camshaft rotates faster. This dependence on the rotational velocity of the crankshaft provides the primary limitation on the use of camshafts.

As the camshaft rotates, cam lobes, attached to the camshaft, interface with the engine's valves. This interface may take place via a mechanical linkage, but the result is, as the cam rotates it forces the valve open. The spring return closes the valve when the cam is no longer supplying the opening force.

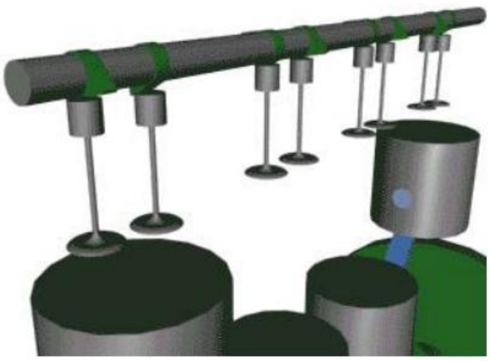
Since the timing of the engine is dependent on the shape of the cam lobes and the rotational velocity of the camshaft, engineers must make decisions early in the automobile development process that affect the engine's performance. The resulting design represents a compromise between fuel efficiency and engine power. Since maximum efficiency and maximum power require unique timing characteristics, the cam design must compromise between the two extremes.

This compromise is a prime consideration when consumers purchase automobiles. Some individuals value power and lean toward the purchase of a high performance sports car or towing capable trucks, while others value fuel economy and vehicles that will provide more miles per gallon.

Recognizing this compromise, automobile manufacturers have been attempting to provide vehicles capable of cylinder deactivation, variable valve timing (VVT), or variable camshaft timing (VCT). These new designs are mostly mechanical in nature. Although they do provide an increased level of sophistication, most are still limited to discrete valve timing changes over a limited range.

II Cam Mechanisms

ISSN: 2057-5688

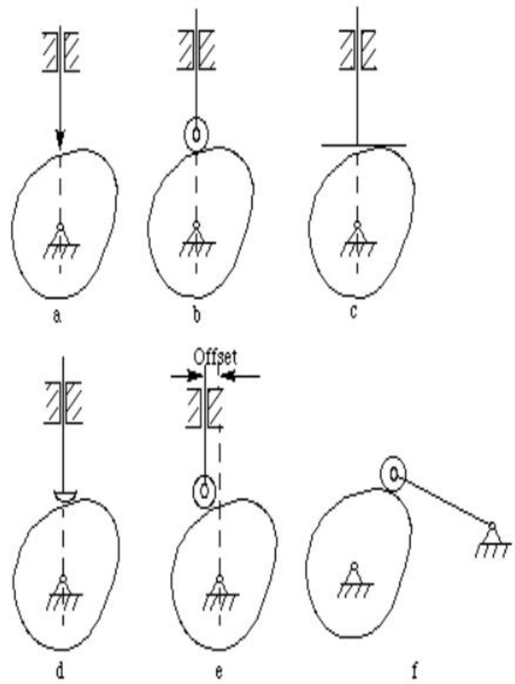


The transformation of one of the simple motions, such as rotation, into any other motions is often conveniently accomplished by means of a cam mechanism A cam mechanism usually consists of two moving elements, the cam and the follower, mounted on a fixed frame. Cam devices are versatile, and almost any arbitrarily-specified motion can be obtained. In some instances, they offer the simplest and most compact way to transform motions.

A 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. The cam 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, and screw machines. In any class of machinery in which automatic control and accurate timing are paramount, the cam is an indispensable part of mechanism. The possible applications of cams are unlimited, and their shapes occur in great variety.

Classification of Cam Mechanisms

We can classify cam mechanisms by the modes of input/output motion, the configuration and arrangement of the follower, and the shape of the cam. We can also classify cams by the different types of motion events of the follower and by means of a great variety of the motion characteristics of the cam profile.



Modes of Input/output Motion

ISSN: 2057-5688

1. Rotating cam-translating follower.

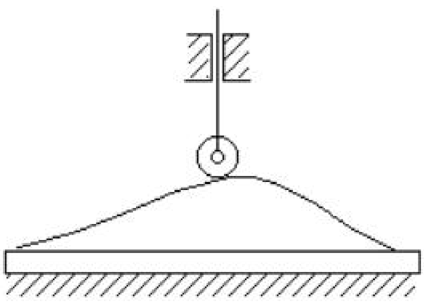
2. Rotating follower

The follower arm swings or oscillates in a circular arc with respect to the follower pivot.

3. Translating cam-translating follower

4. Stationary cam-rotating follower:

The follower system revolves with respect to the center line of the vertical shaft.



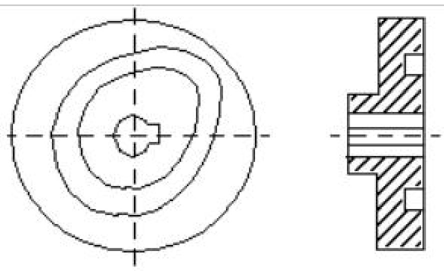
Cam Shape

Plate cam or disk cam:

The follower moves in a plane perpendicular to the axis of rotation of the camshaft. A translating or a swing arm follower must be constrained to maintain contact with the cam profile.

Grooved cam or closed cam:

This is a plate cam with the follower riding in a groove in the face of the cam



Cam Design:

The transnational or rotational displacement of the follower is a function of the rotary angle of the cam. A designer can define the function according to the specific requirements in the design. The motion requirements, listed below, are commonly used in cam profile design.

A 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. Cams play a very important part in modern machinery and are extensively used in internal-combustion engines, machine tools, mechanical computers, instruments and many other applications.

The contour of the cam dictates the cam system's dynamic response. The contour is controlled by the cam's displacement diagram that is created based on design specifications. To analyze the cam's dynamic response the acceleration and jerk of the follower need to be determined. The two parameters can be computed from the cam's displacement diagram.

The same design specifications, two cams (a Tangent Cam and a Curved Cam) with different contours will be tested and analyzed. The formulae for calculating follower displacement, velocity and acceleration are provided below. These formulae were derived from geometrically analyzing the contours of these cams.

Design Specifications:

Cam angle	Tangent Cam	Curved Flank Cam
0° - 90°	25.4 mm (rise)	25.4 mm (rise)
90° - 180°	25.4 mm (fall)	25.4 mm (fall)
180° - 360°	Dwell	Dwell

Tangent Cam with Roller Follower:

Roller in contact with flank

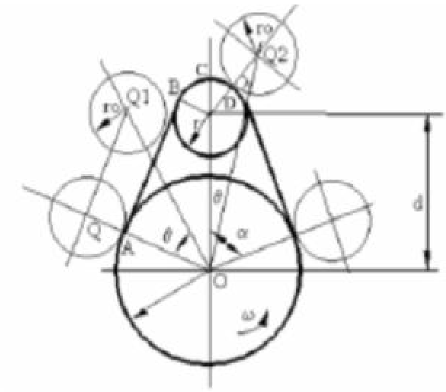
Let R = base circle radius: 25.4 mm

r = radius of nose : 12.7 mm

d = center distance : 38.1 mm

ro = radius of follower : 14.3 mm

Consider the roller follower in contact with the flank AB,



Tangent cam - Roller in contact with flank/ roller in contact with nose.

When the cam has rotated through an angle θ from the lowest position of the follower center Q, displacement of the follower from lowest position, X

X = OQ1 - OQ

= (R + ro) Sec θ - (R + ro) where 0<=θ<=β.

θ = 0 corresponds to the point A and θ=β corresponds to point B

Velocity:

ISSN: 2057-5688

$$V = \omega \frac{dX}{d\theta}$$

= ω (R+ro) Sec θ Tan θ

Acceleration:

$$A = \omega^2 \frac{d^2X}{d\theta^2} = \omega^2 \frac{dV}{d\theta}$$

= ω2 (R - ro) (Sec^{3}θ + Sec θ Tan^{2}θ)

= ω2 (R + ro) (2 Sec^{3}θ + Sec θ)

The range of the cam angle (β) turned while the roller moves from A to B is:

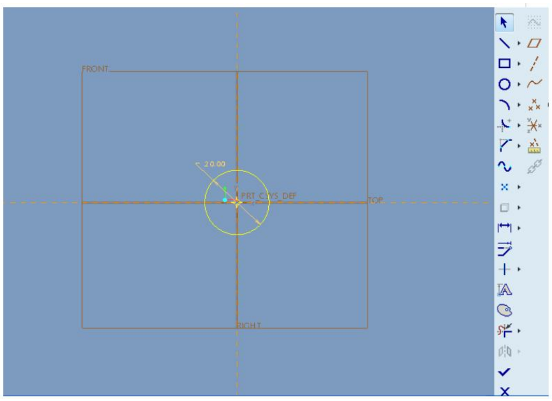
$$Tan\beta = d\frac{\sin\alpha}{R + r_o}$$

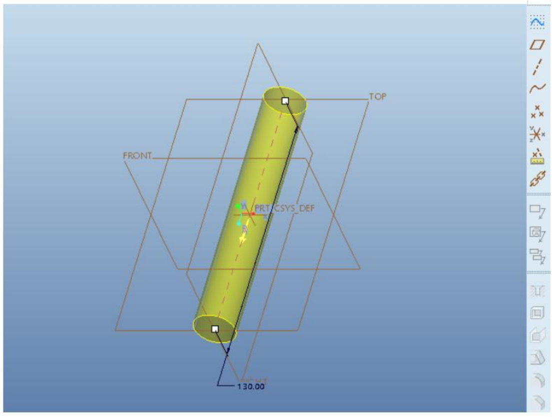
where α is the total angle of lift.

In this case, α = 70.53° and β = 42.14°

III DESIGN OF CAMSHAFT

MAKING OF SHAFT:





First go to part module and enter into sketcher module

Draw a circle of required diameter

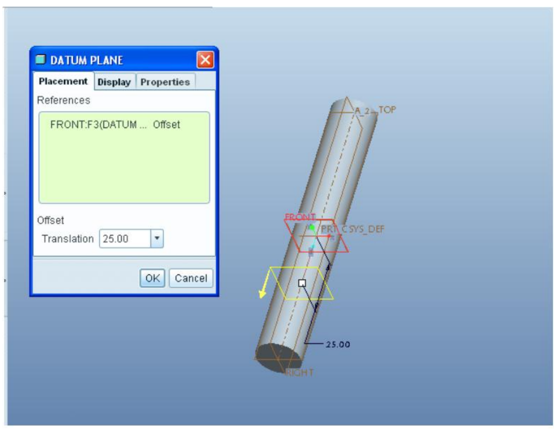
Click on continue option

Place the circle as symmetric

Give the required length of shaft

Click on continue and make the shaft as solid

CREATING A DATUM PLANE:



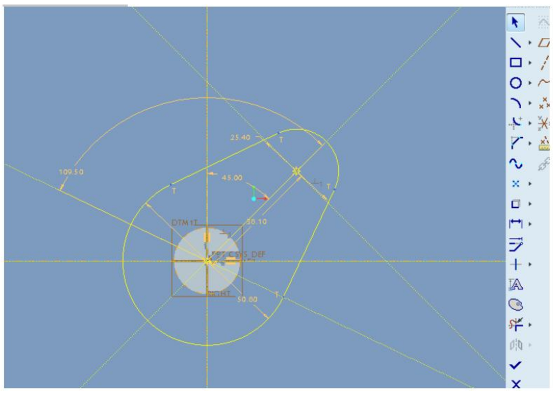
ISSN: 2057-5688

Select the plane to create a datum plane

Give the distance from the reference plane to the datum plane

Click on ok

MAKING OF CAM:



After selecting the datum plane enter into sketcher mode

Draw the axis lines with required angle

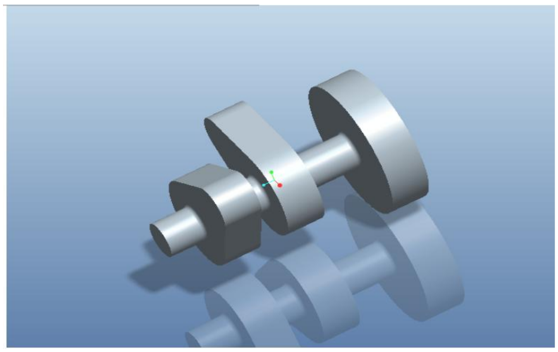
Draw the sketch as required in order to get the cam with the help of circles and tangents

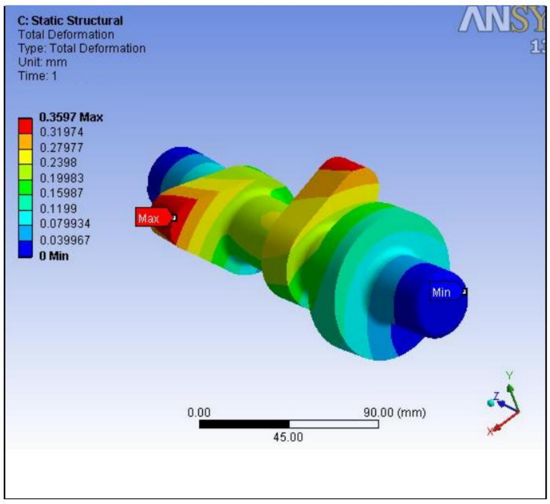
Click on continue

Give the required thickness and click on continue .

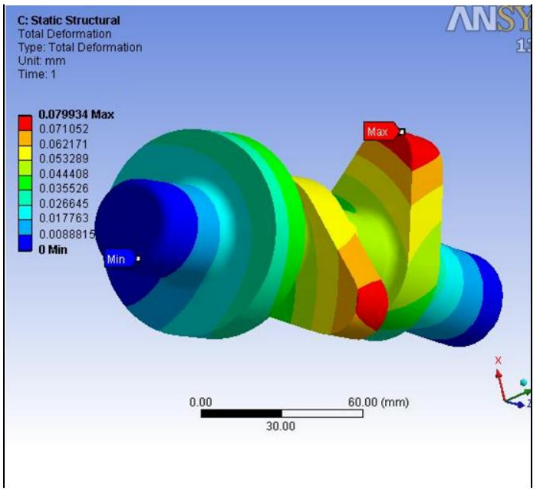
FINAL FIGURE OF CAMSHAFT

FIGURE





ISSN: 2057-5688



IV CONCLUSION

Based on the study conducted, the following conclusions have been summarized below.

•The modal analysis carried out using ANSYS software is compatible with the Dunkerley's calculations with a difference of 4.5%

•Determination of natural frequency is important for the understanding of the resonance phenomenon which occurs when the vibration comes in context with the natural frequency. The operating frequency of the camshaft is 25 Hz which is fairly away from the natural frequency of the camshaft i.e. 400.8 Hz; hence the system is safe from resonance.

•The alternating stress calculated using ANSYS module is 11.22 MPa, and the result closely agree with Lederberg, Goodman and Gerber criterion

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