การวิเคราะห์ลูกเบี้ยว(Cam Analysis)

<u>วัตถุประสงค์</u>

1. เพื่อสร้างเส้นโค้งที่เกิดการยกระดับแตกต่างกันสำหรับ ลูกเบี้ยว(Cam)ต่างๆที่จัดมาให้

2. สังเกตผลกระทบของ Followerที่เกิดการยกตัว

3.เพื่อศึกษาเข้าใจถึงหลักการทำงานของลูกเบี้ยว

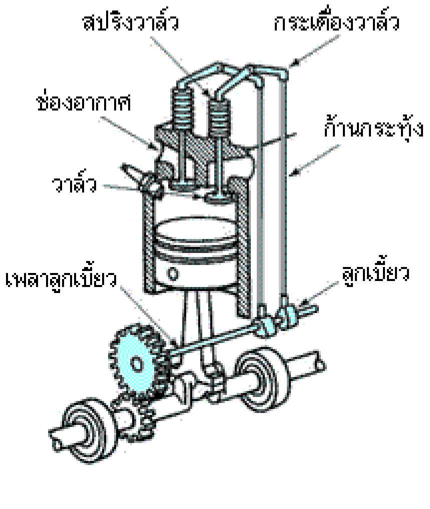
4.เพื่อศึกษาของดีข้อเสียของแคมแต่ล่ะแบบ

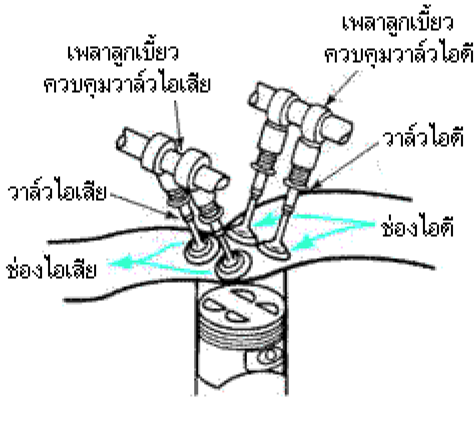
5.เพื่อศึกษาการวิเคราะห์การเคลื่อนที่ ความเร็ว ความเร่ง ที่เกิดจากการทำงานของลูกเบี้ยว

<u>ทฤษฎี</u>

<u>หน้าที่ของเพลาลูกเบี้ยว</u>

เพลาลูกเบี้ยว ทำหน้าที่ควบคุมการเปิดวาล์วไอดี (ปิดวาล์วไอเสีย) เพื่อให้ไอดีไหลเข้ามาสู่ห้องเผาไหม้ และเปิดวาล์วไอเสีย (ปิดวาล์วไอดี) เพื่อให้ไอเสียไหลออกไป สรุปคือ เมื่อเพลาลูกเบี้ยวหมุนเมื่อใด ก็จะต้องมี การเปิด-ปิดของวาล์ว (Valve) เกิดขึ้นเมื่อนั้น





PREAMBLE

- This experimental activity is designed to be undertaken in groups.
- Each group, with equal contribution from each member, is to submit a comprehensive report before 5.00 pm on the specified due date. Marks will be distributed equally between both students.
- Rules of the Mechanics laboratory (Room D328, TO in charge: L. Kovacs Room D328G) must be followed:
  - Authorisation from the technical officer in charge must be obtained before using the equipment.
  - Safety equipment must be worn and safety procedures followed when operating the cam analysis machine.
  - The safety guard must be in position when the motor of the cam analysis machine is switched on.
  - Any malfunction or equipment failure must be immediately reported to the technical officer in charge

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1 INTRODUCTION

This experimental project is aimed at applying analytical and experimental techniques to develop an understanding of the behaviour of cams. The follower motion (displacement, velocity and acceleration) of three types of cams will be derived and verified experimentally.

2 EQUIPMENT

The exercise will be based on a TQ® cams analysis machine type TM21 as illustrated in figure 1.

Figure 1. Photograph of cam analysis machine.

The apparatus consists of a D.C. shunt-wound, geared electric motor connected to an extension shaft via a flexible coupling. Each cam is mounted on a keyed taper on the end of the shaft. A flywheel is included to reduce fluctuation in speed caused by the torque required to lift the follower. The motor speed is controlled by the variable speed electrical supply. The apparatus is fitted with a displacement transducer to measure the vertical displacement of the follower respectively. The transducer is connected to a digital storage oscilloscope and Personal Computer fitted with a data acquisition system.

2.1 Follower displacement measurement.

The vertical displacement of the follower is measured with an LVDT (Linear Variable Differential Transformer) type displacement transducer. The transducer is powered with a 15 Volts D.C. supply connected to a signal conditioning unit which produces a voltage signal proportional to displacement.

2.2 Follower acceleration measurement

The vertical acceleration of the follower is obtained by differentiating (twice) the signal produced by the displacement transducer. This is carried out automatically by the PC-based data acquisition system.

2.3 Angular speed measurement

The angular speed of the cam is measured with the digital oscilloscope to which the displacement transducer is connected.

2.4 Data acquisition

The displacement transducer signal is captured with a PC fitted with a 12 Bit data acquisition module. Two software programs are provided to capture the data:

- *Cams Static.vee* continuously captures the signal (volts) and converts it to mm using the transducer's calibration constant.
- *Cams Dynamic.vee* continuously captures the displacement signal (volts) in 1 second long records sampled at 1024 Hz. After conversion to mm, the record is differentiated twice to provide an estimate of vertical follower acceleration. Both the displacement and acceleration records are stored onto the PC's hard disk. As the system updates the 1-second record continually, only the last record before halting the program will be stored.

3 INSTRUCTIONS

3.1 Task 1 – predicting follower motion

Using the geometry and dimensions of the three cams, show that the follower displacement, X, velocity, V and acceleration, a, are as follows:

Tangent cam with roller follower:

Roller in contact with flank:

$$X = OQ_1 - OQ = (R + r_o)Sec(\theta) - (R + r_o)$$
$$V = \omega(R + r_0)Sec(\theta)Tan(\theta)$$
$$a = \omega^2 (R + r_0)\left[Sec(\theta)Tan^2(\theta) - Sec^3(\theta)\right]$$

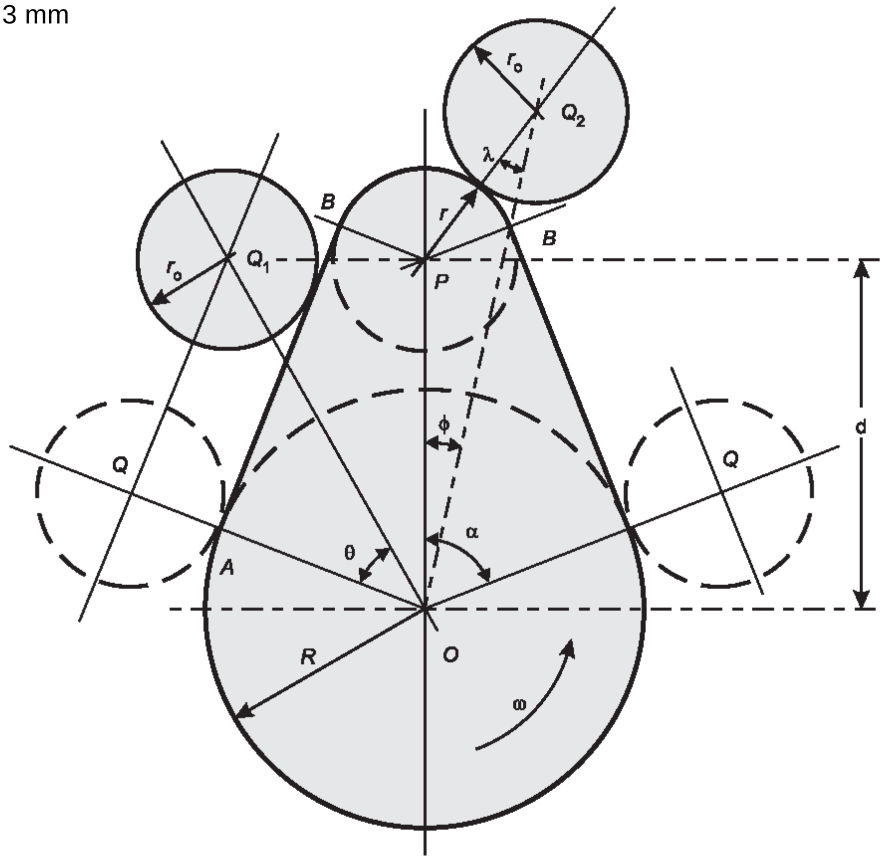
Roller in contact with nose:

$$X = d\left\{cos(\phi) + \sqrt{n^2 - sin^2(\phi)}\right\} - (R + r_o) \qquad where \;\; n = \frac{r + r_0}{d}$$

$$V = -\omega d\left\{sin(\phi) + \frac{sin(2\phi)}{2\sqrt{n^2 - sin^2(\phi)}}\right\}$$

$$a = -\omega^2 d\left\{cos(\phi) + \frac{sin^4(\phi) + n^2 cos(2\phi)}{\left(n^2 - sin^2(\phi)\right)^{3/2}}\right\}$$

- R = base circle radius = 25.4 mm
- r = nose radius = 12.7 mm
- d = centre distance = 38.1 mm
- r_o = follower radius = 14.3 mm



Convex cam with roller follower.

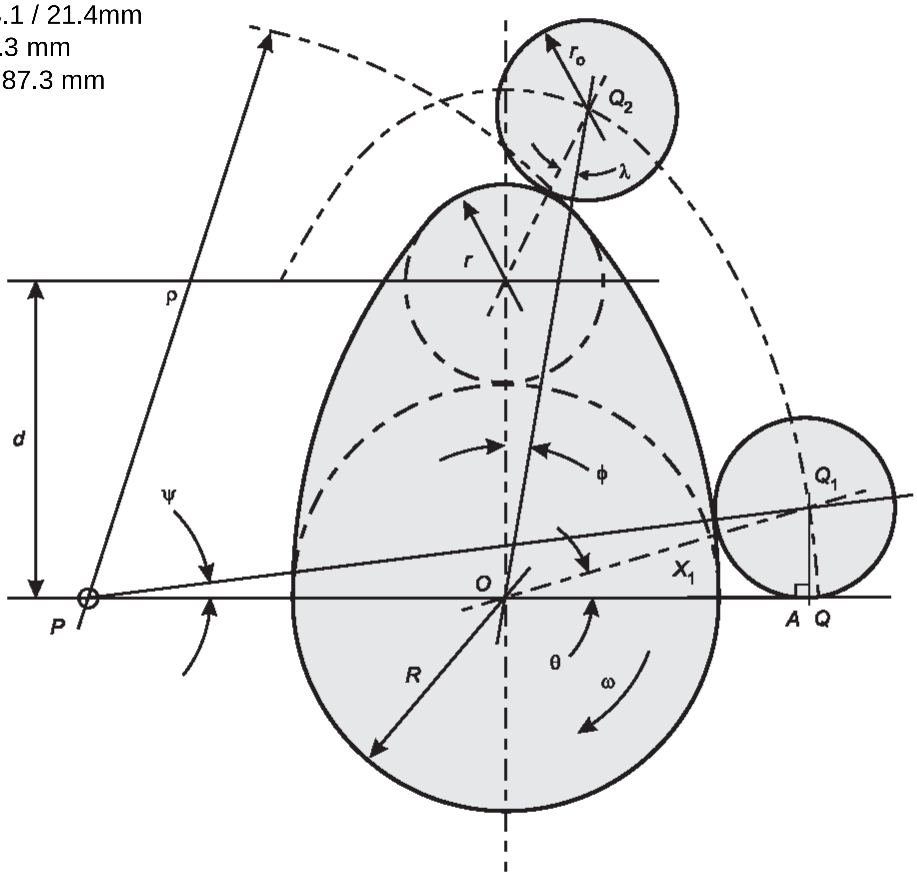
$$X=(\rho+R)\left\{\sqrt{\cos^2(\theta)\frac{(\rho+r_0)^2}{(\rho-R)^2}-1}-\cos(\theta)-\frac{(R+r_0)}{(\rho-R)}\right\}$$

$$V=(\rho-R)\omega\left\{\sin(\theta)-\frac{\sin(2\theta)}{\sqrt{\cos^2(\theta)\frac{(\rho+r_0)^2}{(\rho-R)^2}-1}}\right\}$$

$$a=(\rho-R)\omega^2\left\{\sin(\theta)-\frac{\cos(2\theta)\left[\cos^2(\theta)\frac{(\rho+r_0)^2}{(\rho-R)^2}-1\right]+\frac{1}{4}\sin^2(2\theta)}{\left[\cos^2(\theta)\frac{(\rho+r_0)^2}{(\rho-R)^2}-1\right]^{3/2}}\right\}$$

When the follower is in contact with the nose, the same equations as applied to the tangent cam apply.

- R = base circle radius = 25.4 / 30.2 mm
- r = nose radius = 12.7 / 25.8 mm
- d = centre distance = 38.1 / 21.4mm
- r_o = follower radius = 14.3 mm
- ρ = flank radius = 79.4 / 87.3 mm



Concave cam with roller follower.

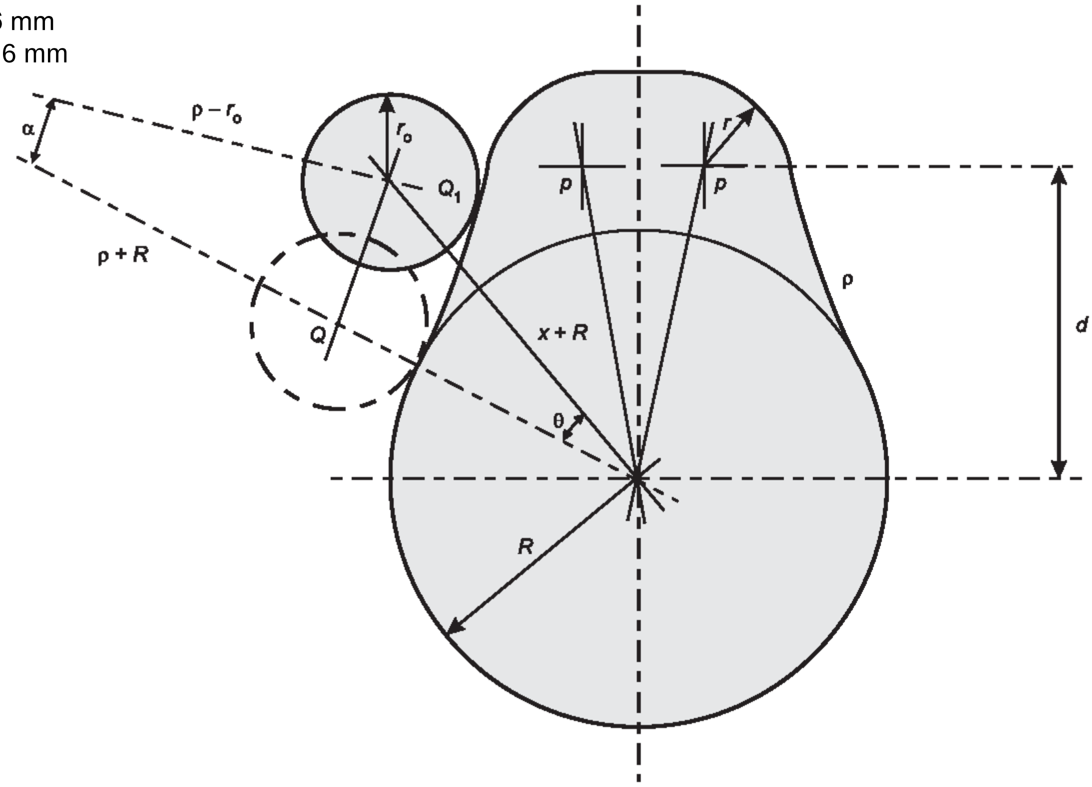
$$X = (\rho + R)\left\{ cos(\theta) - \sqrt{cos^2(\theta)\frac{(\rho - r_0)^2}{(\rho - R)^2} - 1} - \frac{(R + r_0)}{(\rho + R)} \right\}$$

$$V = (\rho + R)\omega\left\{ -sin(\theta) + \frac{sin(2\theta)}{\sqrt{cos^2(\theta)\frac{(\rho - r_0)^2}{(\rho + R)^2} - 1}} \right\}$$

$$a = (\rho + R)\omega^2\left\{ -cos(\theta) + \frac{\left[cos^2(\theta)\frac{(\rho - r)^2}{(\rho + R)^2} - 1\right]Cos(2\theta) + \frac{1}{4}sin^2(2\theta)}{\left[cos^2(\theta)\frac{(\rho - r_0)^2}{(\rho + R)^2} - 1\right]^{3/2}} \right\}$$

When the follower is in contact with the nose, the same equations as applied to the tangent cam apply. The distance OP is used instead of d

- R = base circle radius = 30.2 mm
- r = nose radius = 12.7 mm
- d = centre distance = 38.1 mm
- r_o = follower radius = 14.3 mm
- ρ = 101.8 mm
- R' = 51.6 mm
- OP = 38.6 mm



3.2 Task 2 – Predicting follower bounce

Derive a generic equation for the dynamic vertical force acting on the follower as a function of follower displacement, acceleration and nominal spring deflection.

For each in the three cams and for an arbitrary spring deflection, predict the angular speed at which follower bounce will occur.

- Follower mass (including instruments): 1.800 kg
- Nominal spring stiffness: 3.73 kN/m
- Spring adjustment screw pitch: 2.54 mm

3.3 Task 3 – Measuring cam geometry, acceleration and follower bounce.

a) **Ensure that the motor controller is switched off and electrically disconnected from the motor.** Using the graduation on the flywheel (5^0 per graduation) and using the *Cams static.vee* program on the PC measure the actual profile of each of the three cams.

b) Using the *Cams dynamic.vee* on the PC, measure the velocity and acceleration curves for each of the three cams for an arbitrary angular speed. The data will be stored in ASCII text format, make sure that you store the data in a file with a unique name.

c) After setting the spring to the same arbitrary nominal spring deflection used in Task 2, measure the speed at which follower bounce occurs for each of the three cams.

MAKE SURE ALL INSTRUMENTS ARE SWITCHED OFF BEFORE LEAVING THE LABORATORY.

3.4 Task 4 – Analysing results

Compare and discuss the results obtained from task 1 and 3(a).
Compare and discuss the results obtained from task 1 and 3(b).
Compare and discuss the results obtained from task 2 and 3(c).