Retrofitting of Existing Cam Follower Mechanism for Computer Aided Kinematic Analysis

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Abstract- Cam-follower mechanisms are most widely used in various mechanical machineries such as automatic machines, machine tools, IC engines, etc.In this research paper, the complete kinematic analysis is being done to determine the displacement of follower for different rotation angles of cams. The analytical calculations with required experimentations are being doneto determine the displacement of follower for different rotation angles of cams.Usingpotentiometric linear motion sensor and absolute encoder with the required data acquisition system,having Mega 328 Microcontroller is used to find results after integrating with computer for kinematic analysis. Thecomparisons between real-time and analytical results for follower displacements corresponding to cam rotation angles have been done in MATLAB.

Keywords: Analytical model, Cam-follower, Potentiometric linear motion sensor, Analog Rotary Position Sensor, Tangent Cam, Eccentric Cam, Data Acquisition System, Kinematic analysis

1. Introduction

A cam is a mechanical element used to drive another element, called the follower through a specified motion by direct contact [1]. When the nature of follower motion is specified and the corresponding cam profile is determined, in many cases such cams are difficult and costly to manufacture, since a master cam has first to be made, mostly by hand, and then used as a standard model in the production of other cams of the same shape. From the viewpoint of accuracy of profile and cheapness of manufacture it is much better to form the cam profile of circular arcs and straight lines.

The nature of motion given to the follower may then be determined [2].Tangent andCircular Cams are generally used in internal combustion engine practice.The aim of this work is to apply analytical and experimental techniques to develop an understanding of the behavior of cam and follower. In this paper, kinematic analysis is carried out for tangent cam and roller follower.

1.1. Kinematic analysis

Kinematic analysis involves the determination of displacement of follower at different cam rotation angles. Equations governing the motion of follower from the literature are used for displacement of followers [3].

1.2. Survey of Computer Aided Kinematic Analysis of cam and follower

1.2.1. Tangent cam with roller follower

In tangent cam, the flanks between the nose and base circles are straight and tangential to both circles. Tangent cam is generally symmetrical about the centre line of cam.A roller follower consists of a cylindrical roller which rolls on the cam surface.The rate of wear is considerably reduced as compared to knife edge follower.Consider a tangent cam having centre of cam at O_1 and that of the nose at O_2. The straight flank commences from point Aand continues till it meets arc of the nose radius at point E [3].

Let r = distance between the cam and nose centers

r_1 =Base circle radius or least radius

r_2 =Nose radius

r_r = Radius of roller

$r = r_1 + \text{lift} - r_2$

θ=angle of cam rotation

β= angle of ascent or rise , $\cos\beta = \frac{r_1 - r_2}{r}$

x= displacement of follower

Case 1

Roller in contact with flank

Consider a tangent cam with roller follower in contact with straight flank. The centre of the roller lies at point C on the pitch curve as shown in fig.1 [3].

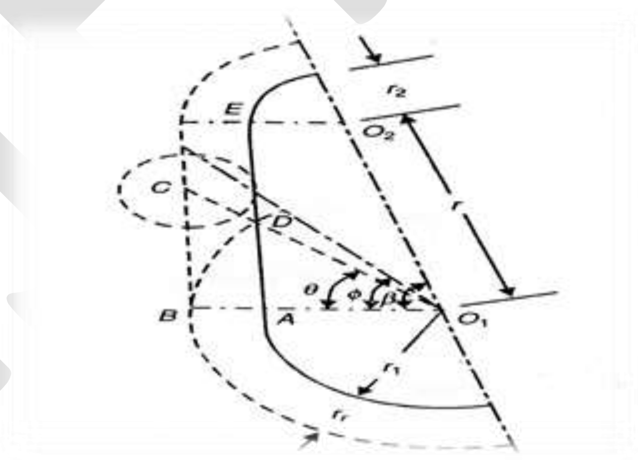


Fig.1. Tangent cam with roller follower in contact with straight flank[3]

Let angle turned by the cam from its original position i.e. beginning of the follower motion is θ° [3]:

$$x = (r_1 + r_r)\left(\frac{1}{\cos\theta} - 1\right) \text{ where } r_1 = 14.5 \text{ mm and } r_r = 15\ mm \text{ for the test cam}$$

Case 2

Roller in contact with circular nose

Consider the case when roller follower is in contact with nose. The centre of the roller lies at point C on the pitch curve of nose as shown in fig. 2[3]:

$$x = r\left\{cos\ (\beta - \theta) + \sqrt{n^2 - sin^2(\beta - \theta)}\right\} - (r_1 + r_r) \text{ where } n = \frac{r_2 + r_r}{r}$$

$$\text{And} r = 14.3 \text{ mm,} r_2 = 10\ mm \text{ for the test cam}$$

At the beginning of lift, θ=0°

$$tan\ \theta = \frac{rsin\beta}{r_1 + r_r}\ where\ r = 14.3 \text{ mmfor the test cam}$$

At this value of θ, straight flank merges into circular nose. $\beta = 72°$

When roller is at the apex of circular nose, θ=β and hence,

$$\emptyset = \beta - \theta = 0$$

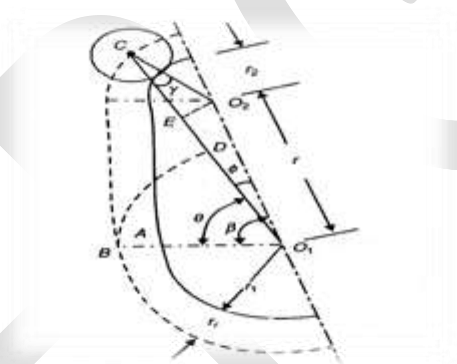
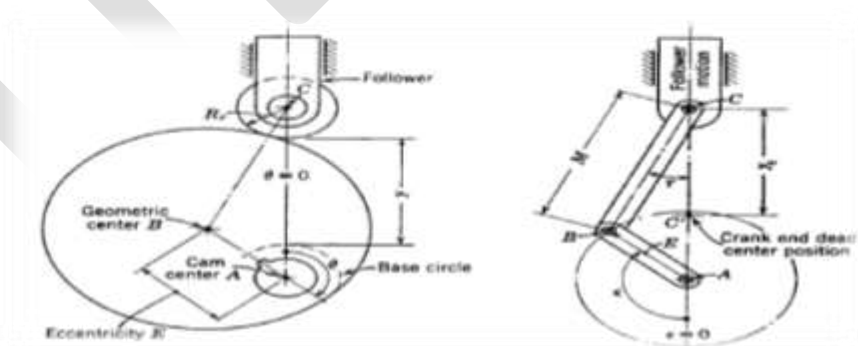


Fig.2. Tangent cams with roller follower in contact with nose of the cam[3]

1.2.2. Eccentric cam with roller follower



(a) Cam and follower **(b) Equivalent mechanism**

Fig. 3 Eccentric cam with roller follower [4]

Displacement of follower for eccentric cam is given by $y = E - E\cos\epsilon + M\cos\tau - M$

Where,

M: Equivalent mechanism connecting rod length = 33.65 mmfor the test cam

τ: Angle between connecting rod and follower motion = 4.99 °

ϵ: Cam rotation angle

2. Existing experimental set up

The machine is a motorized unit consisting of a cam shaft driven by a DCshunt motor. The shaft and double ball bearing are used. A cam can be easily mounted at the end of camshaft.The follower has linear reciprocating motion and the type of the follower can be changed to suit the cam fitted to note the follower displacement for the angle of cam rotation. A spring is used to provide controlling force to the system. Weights on the follower rod can be adjusted as per requirements. The arrangement is provided to vary the speed of cam shaft. The displacement of follower is measured by the dial gauge. The angle of cam rotation is measured by the angular scale fitted to the apparatus.

3. Proposed developments

It is proposed to convert old cam follower set up with computerized one, so that various measurements such as displacement of follower will be recorded in Data Acquisition system.

After rigorous literature survey, it has been found that we can integrate existing set up with potentiometric linear motion sensor and absolute encoder, data acquisition system and thus to computer [5, 14].

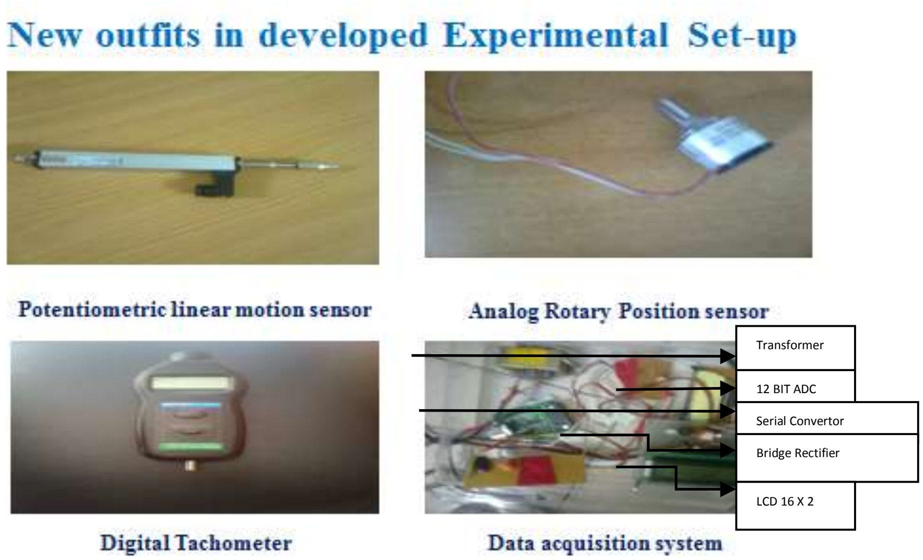


Fig.4. Displacement and angle sensors

New outfits included are:

- Potentiometric linear motion sensor, MTR18B Analog Output, for measuring follower displacement as shown in fig.4
- Analog Contactless Rotary Position Sensor, Series 22A RCBL, for measuring angle of rotation of cam as shown in fig.4.
- Digital advanced Tachometer, MEXTECH DT-2236C, for measuring speed of rotation of cam as shown in fig.4.
- Data acquisition system having Mega 328 Microcontroller for interfacing cam follower with computer as shown in fig.5.
- Computer having MATLAB software for plotting graphs of cam rotation angle versus follower displacement as shown in fig.5.

Fig.5. Data acquisition system

Fig.6. Developed Cam follower mechanism

The retrofitted experimental set up is shown in Fig. 6.

4. Results

Analytical and real-time values for follower displacement in mm are shown for cam rotation angle from 0° to 360°, for tangent cam and roller follower at 300 rpmmotor speed in table 1.

Table 1.Analytical and Real-Time Results for Tangent Cam andRoller Follower

Sr. no	Angle in Degrees	Displacement in mm (analytical)	Displacement in mm (real-time)	Sr. no	Angle in Degrees	Displacement in mm (analytical)	Displacement in mm (real-time)
1	0	0.00	0.00	20	180	0.00	0.00
2	10	0.46	0.44	21	190	0.00	0.00
3	20	1.89	1.74	22	200	0.00	0.00
4	30	4.31	3.66	23	210	0.00	0.00
5	40	6.52	6.29	24	220	0.00	0.00
6	50	8.23	8.14	25	230	0.00	0.00
7	60	9.34	9.02	26	240	0.00	0.00
8	70	9.79	9.11	27	250	0.00	0.00
9	72	9.83	9.32	28	260	0.00	0.00
10	80	9.60	8.74	29	270	0.00	0.00
11	90	8.75	8.19	30	280	0.00	0.00
12	100	7.27	7.09	31	290	0.00	0.00
13	110	5.24	5.02	32	300	0.00	0.00
14	120	2.79	2.64	33	310	0.00	0.00
15	130	0.90	0.87	34	320	0.00	0.00
16	140	0.07	0.07	35	330	0.00	0.00
17	150	0.00	0.00	36	340	0.00	0.00
18	160	0.00	0.00	37	350	0.00	0.00
19	170	0.00	0.00	38	360	0.00	0.00

In MATLAB, graphs have been plotted for tangent cam by both analytical and real-time ways, as shown in fig.7.

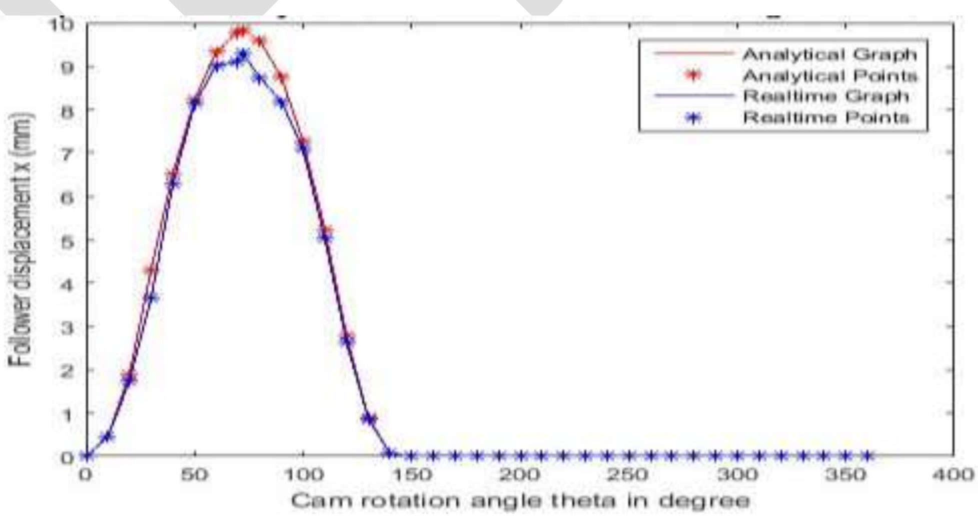


Fig. 7. Comparison of Analytical and Real-time results for Tangent cam

Analytical and real-time values for follower displacement in mm are shown for cam rotation angle from 0° to 360°, for Eccentric cam and roller followerat 300 rpm motor speed in table 2.

Table 2.Analytical and Real-Time Results for Eccentric Cam andRoller Follower

Sr. no	Angle in Degrees	Displacement in mm (analytical)	Displacement in mm (real-time)	Sr. no	Angle in Degrees	Displacement in mm (analytical)	Displacement in mm (real-time)
1	0	0.00	0.00	20	190	11.60	10.77
2	10	0.07	0.07	21	200	11.29	10.44
3	20	0.30	0.27	22	210	10.79	9.77
4	30	0.66	0.66	23	220	10.13	9.51
5	40	1.17	1.10	24	230	9.32	9.24
6	50	1.80	1.71	25	240	8.41	8.41
7	60	2.56	2.36	26	250	7.42	7.09
8	70	3.42	3.26	27	260	6.39	6.21
9	80	4.36	4.30	28	270	5.36	5.03
10	90	5.36	5.07	29	280	4.36	4.30
11	100	6.39	6.15	30	290	3.42	3.33
12	110	7.42	7.35	31	300	2.56	2.48
13	120	8.41	8.34	32	310	1.80	1.60
14	130	9.32	9.02	33	320	1.17	1.17
15	140	10.13	9.62	34	330	0.66	0.66
16	150	10.79	9.67	35	340	0.30	0.30
17	160	11.29	9.71	36	350	0.07	0.07
18	170	11.60	10.29	37	360	0.00	0.00
19	180	11.70	10.81				

In MATLAB, graphs have been plotted for Eccentric cam by both analytical and real-time ways, as shown in fig. 8.

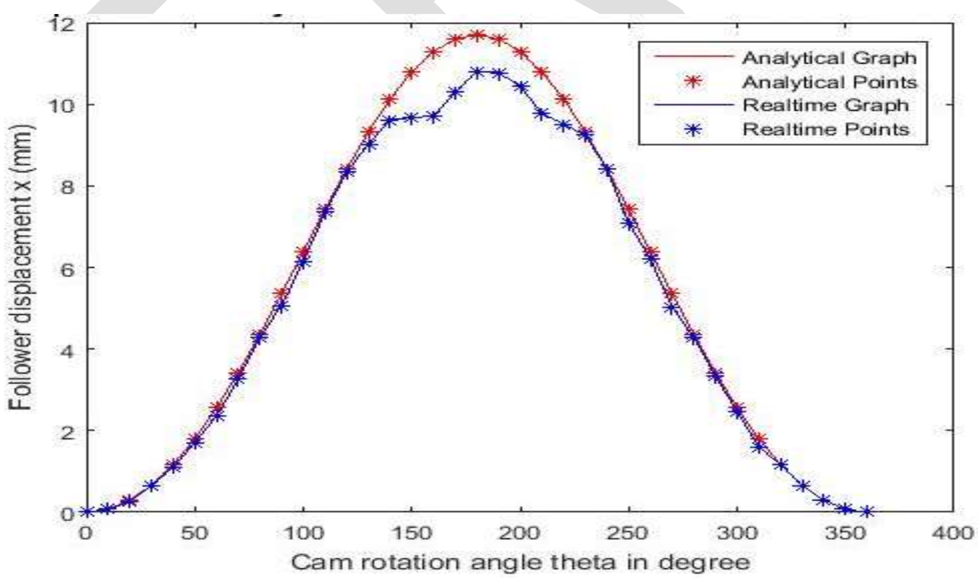


Fig.8. Comparison of Analytical and Real-time results for Eccentric cam

5. Conclusion

Retrofitted Cam Follower Mechanism has been outfitted with new accessories which arePotentiometric linear motion, Analog Contactless Rotary Position Sensor, Digital advanced Tachometer, Data acquisition system and Computer having MATLAB software.

These have facilitated in getting advantages including fast computations, accuracy of final results. Further, we have fabricated suitable fixture for the same, manufacturing of Tangent Cam and Eccentric circle cam as per standards has been done.

During comparisons for Tangent Cam, 3 % deviation (in between analytical and real time) is observed which is not as significant. However for Eccentric Cam, 4 % deviation is noted and that too because of variation in profile of cams (eccentric cam has different profile as compared to tangent cam). And therefore, it can be said that in either case graphs are almost matching. And the reasons behind slight variations (3 % and 4 % deviations) are sudden changes in acceleration which finally induces jerk and thereby inducing vibrations and noises in Cam and Follower Mechanism.

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