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KINEMATIC AND DYNAMIC ANALYSIS OF CAM AND FOLLOWER USING MATLAB

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A B S T R A C T

In this paper, the complete kinematic and dynamic analysis of cam and follower is done and critical angular speed is determined for each design to predict when the follower jumps off the cam. Analytical method is used, as it is more accurate and less time consuming and if programmed for the complete solution. The dynamic force analysis determines the cam contact forces and values of kinematic parameters at which the design fails. The analytical calculation is done in excel sheet for both kinematic and dynamic analysis of cam follower system for any rotational speed and angle of rise.

1. INTRODUCTION

A cam is a rotating machine element which gives reciprocating or oscillating motion to another element known as follower. The cam and the follower have a line contact and constitute a higher pair. The cams are usually rotated at uniform speed by a shaft, but the follower motion is predetermined and will be according to the shape of the cam. The cam and follower is one of the simplest as well as one of the most important mechanisms found in modern machinery today.

In this paper, complete kinematic and dynamic analysis of cam and follower mechanism is carried out using analytical method. The equations for governing motion of the follower have been taken from the literature (Rattan, 2003).

The kinematic analysis of mechanism helps in answering many questions related to motion of the follower.

In this present work displacement, velocity and acceleration values are calculated at each 10^0 rotation of cam using analytical relations. Fig.1 shows cam follower assembly.

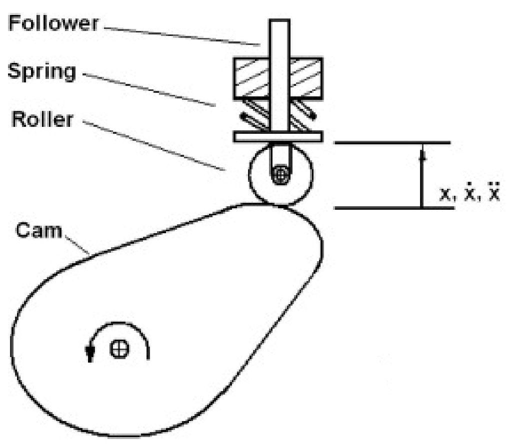

Figure 1. Cam follower assembly

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The dynamic analysis includes the static and inertia force analysis of the follower. For normal working of mechanism, the resultant vertical force has to be in downward direction. If the instant force changes its direction, lifting of follower will take place and design will fail. In this paper kinematic parameters and forces are calculated analytically and critical angular speed of rotation is found for the design specification. The equations have been programmed for the computer solution for rotation of cam by an interval of 10^0.

2. KINEMATIC ANALYSIS

Kinematic analysis involves the calculations of displacement, velocity and acceleration of the follower at different instant. Empirical relations from the literature are used for displacement (Rattan, 2003). By differentiation we can get velocity and acceleration.

Equations for various governing motions of follower (Norton, 2002):

Cycloidal Motion

$$y = d\left\{\theta/\beta - 1/2\pi\left(\sin 2\pi\theta/\beta\right)\right\}$$
$$y' = d\omega/\beta\left(1-\cos 2\pi\theta/\beta\right)$$
$$y'' = 2d\pi\left(\omega/\beta\right)^2 \sin 2\pi\theta/\beta$$

Simple Harmonic Motion

$$y = d/2\left\{1-\cos \pi\theta/\beta\right\}$$
$$y' = \left(\pi d\omega/2\beta\right)\sin \pi\theta/\beta$$
$$y'' = d/2\left(\pi\omega/\beta\right)^2 \cos \pi\theta/\beta$$

Parabolic motion

$$y = 2d\left(\theta/\beta\right)^2$$
$$y' = 4\omega d\,\theta/\beta^2$$
$$y'' = 4\omega^2 d\,\theta/\beta^2$$

Where:

$\boldsymbol{d}$- Lift of the follower
$\boldsymbol{\beta}$- Angle of rise
$\boldsymbol{\theta}$- Angular displacement of cam
$\boldsymbol{y}$- vertical displacement of follower

Kinematic analysis of mechanism helps in determining the cam torque or torque delivered to the rotating cam. Using instantaneous centre of rotation of link 2 and link 4 we get torque delivered to the cam (figure 2).

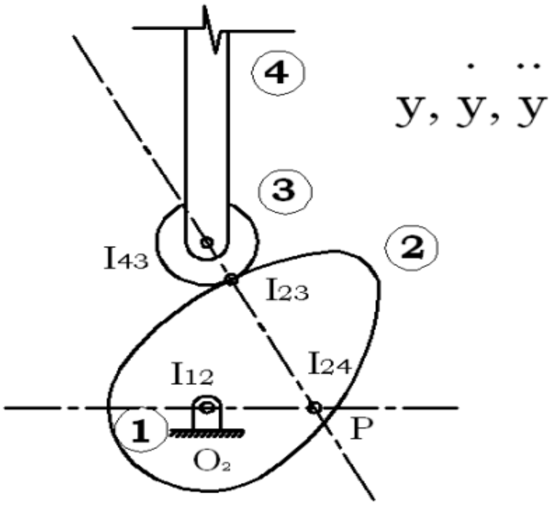


Figure 2. Instantaneous centres of the cam

Now we have,

$$v_p = \dot{y} = \omega_2 \times O_2P$$
$$O_2P = \left(\dot{y}/\omega_2\right)$$
$$T_2 = F_{32}^{Y} \times O_2P$$
$$F_{32}^{Y} = P + F_s + \left(-m\ddot{y}\right)$$

Where:
$\dot{y}$ -Velocity of follower,
$\ddot{y}$- Acceleration of the follower,
ω_2- Angular Velocity of Cam,
T_2- Torque delivered to the cam,
F_{32}- Reaction of link 3 on link2,
m- Mass of follower,
F_s- Spring force,
P- Force due to load.

For finding F_{32}, dynamic analysis is done. Using the equations of displacement, values of all kinematic parameters are calculated with the help of computer program.

3. DYNAMIC ANALYSIS

Dynamic analysis of follower gives resultant force acting on it in vertical direction which is directly related to the motion of follower. The negative sign of the resultant force ensures that the net downward force on the follower maintains its contact with the cam, through an idler roller. This remains so until it reaches a critical speed. Beyond the critical speed, the resultant force becomes positive and act in upward direction, which results in lifting of the follower, leaving its contact

with the cam. Such situation is called jump of follower and the design fails to give desired performance.
Free body diagrams of link2, 3 and 4 are shown in Figure 3.

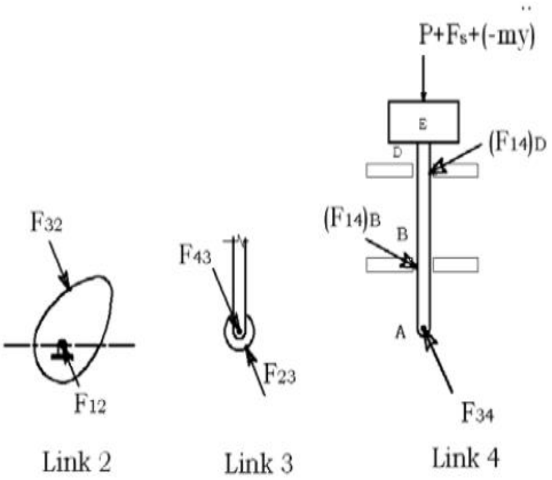


Figure 3. Free body diagrams of cam, roller and follower

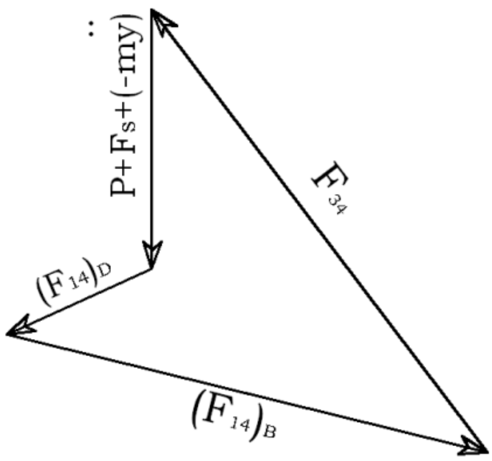


Figure 4. Free polygon of forces acting on link 4

4. RESULT

The results computed from the program developed for kinematic and dynamic analysis of the follower are given for each 10^0 rotation of cam. The results of kinematic analysis of the follower gives values of displacement, velocity and acceleration at different instants, which is shown in table 1, parabolic motion.
Considering

$$h = 0.018m$$
$$\omega_2 = 62.83\, rad/\sec$$
$$m = 1.6\, kg$$
$$\beta = 150^0$$

The result from dynamic analysis gives the resultant vertical force on the follower and torque delivered to cam. Table 2 shows Inertia Force, Spring Force, Resultant Force and torque according to cam rotation angle for parabolic motion.

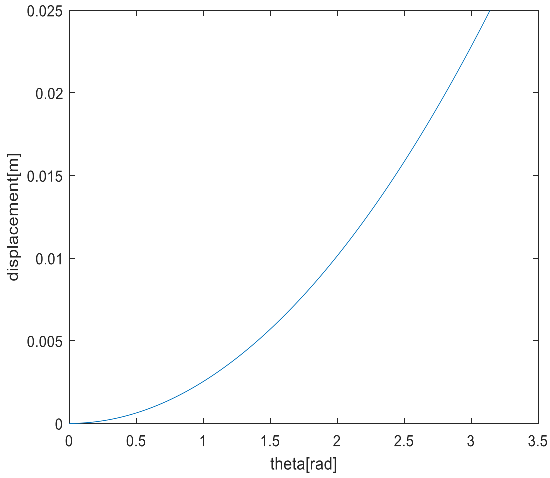
The variation of velocity and acceleration is shown in Figure 5 Similarly the variation of different forces with respect to cam angle is shown in Figure 6. The knowledge of resultant force decides the critical angular velocity of the cam which is essential for the design of the cam mechanism.

Table 1. Displacement, Velocity and Acceleration of Follower according to Cam Rotation Angle.

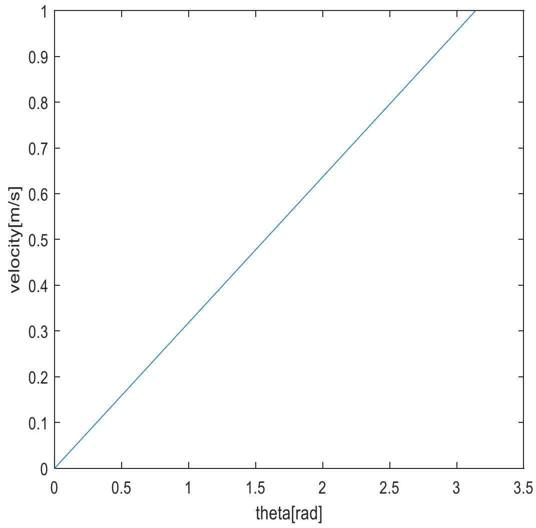
Angle of Rotation of Cam θ	Displacement of Follower y	Velocity of Follower y'	Acceleration of Follower y''
0	0	0	0
10	0.00016	0.1152	7.2378
20	0.00064	0.2304	14.4756
30	0.00140	0.3456	21.7134
40	0.00260	0.4608	28.9512
50	0.0040	0.5760	36.1890
60	0.0058	0.6912	43.4268
70	0.0078	0.8064	50.6646
80	0.0102	0.9216	57.9024
90	0.0130	1.0368	65.1402
100	0.0160	1.1520	72.3780
110	0.0194	1.2672	79.6158
120	0.0230	1.3824	86.8536
130	0.0270	1.4976	94.0914
140	0.0314	1.6128	101.3292
150	0.0360	1.7279	108.5670

Table 2. Inertia Force, Spring Force, Resultant Force according to Cam Rotation Angle.

Angle of Rotation of Cam θ	Inertia Force F_{in}	Spring Force F_s	Resultant force F_R
0	0	0	0
10	-11.5805	1.6	13.1805
20	-23.1610	6.4	29.561
30	-34.7415	14.4	49.1415
40	-46.3219	25.6	71.9219
50	-57.9024	40	97.9024
60	-69.4829	57.6	127.0829
70	-81.0634	78.4	159.4634
80	-92.6439	102.4	195.0439
90	-104.2244	129.6	233.8244
100	-115.8048	160	275.8048
110	-127.3853	193.6	320.9853
120	-138.9658	230.4	369.3658
130	-150.5463	270.4	420.9436
140	-162.1268	313.6	475.7268
150	-173.7073	360	533.7073



(A)



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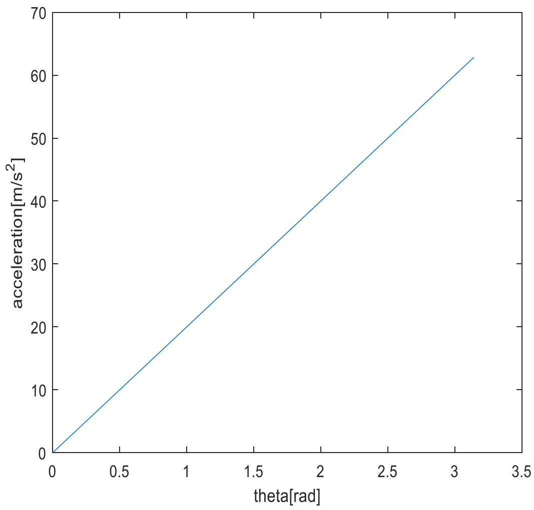
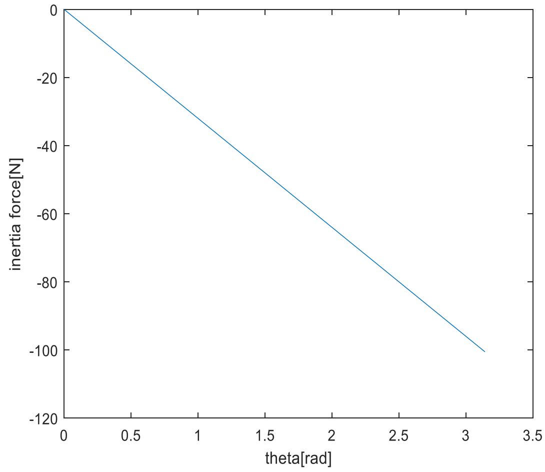
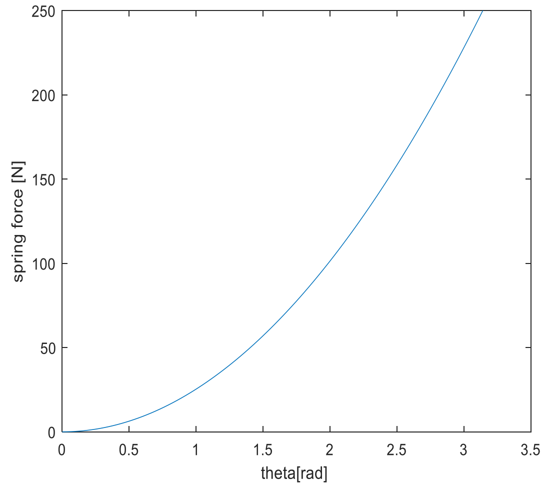


(C)

Figure 5. (A) Displacement, (B) Velocity and (C) Acceleration of follower according to Cam rotation Angle.



(A)



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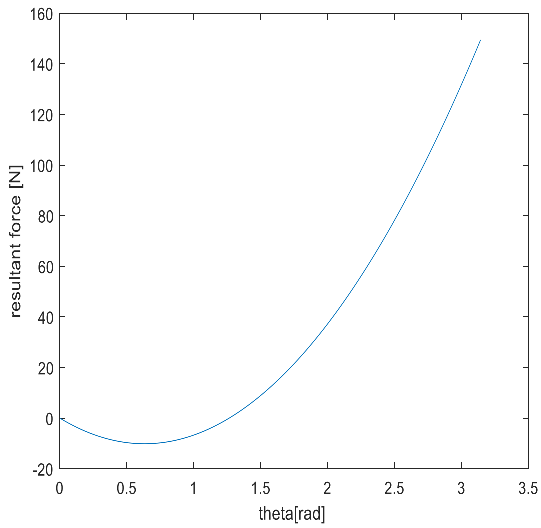

(C)

Figure 6. (A)Inertia Force, (B) Spring Force, (C) Resultant Force on follower according to Cam rotation Angle.

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