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Research Paper

COMPUTER AIDED KINEMATIC ANALYSIS AND SIMULATION OF THE CAM-FOLLOWER MECHANISM

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Cam and follower are widely used in regulating, opening and closing of valves (inlet and exhaust) in the internal combustion engines. Proper design of cam and follower is required for perfect tuning between opening and closing of valves with cam shaft speed. In this paper, the complete kinematic analysis of cam and follower is done continued with simulation. Simulation involved with experimentation of computerized model of a system of process. Simulation is a very general method of studying problems. it generally involve complex problem in case where actual test may not be practical. The analytical calculation is done in excel sheet for kinematic analysis of cam follower system for any rotational speed and angle rise and simulation is done.

Keywords: Analytical model, Cam-follower, Servo motor

INTRODUCTION

Cams are commonly used in opening and closing of valves in internal combustion engines. Both the inlet and outlet valves are regulated using cam and follower. The study of cam and follower mechanism becomes important for desired and required performance of the engines. 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 (Shigley and Joseph, 2003). The Simulation is the process of designing a model of a real system and conducting experiments on the model for the purpose of understanding the behavior of the system or of evaluating various strategies for the operation of the system. It is a tool to predict the behavior of the physical system under certain condition.

KINEMATIC ANALYSIS

Kinematic analysis involves the calculations of displacement, velocity and acceleration of the follower at different instant. Empirical relations

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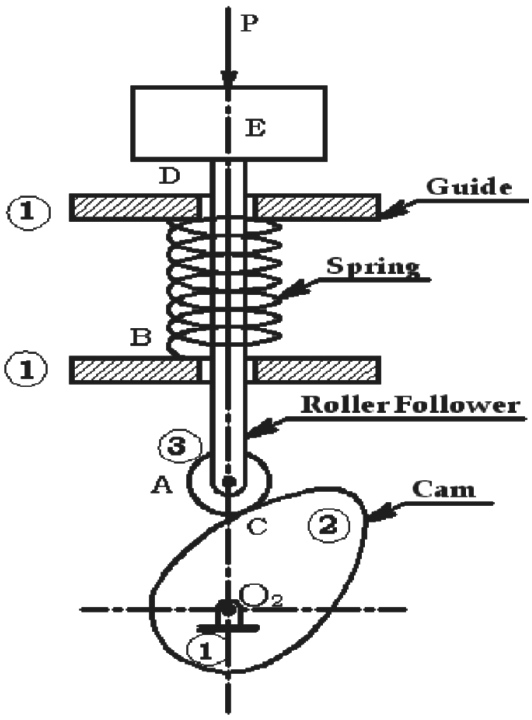
Figure 1: Cam Follower Assembly



from the literature are used for displacement. Shigley and Joseph (2003) by differentiation we can get velocity and acceleration.

Equations for various governing motions of follower (Shigley and Joseph, 2003):

- Cycloidal Motion

$$y = h[(\theta/\beta) - (1/2\pi) \times \sin(2\pi\theta/\beta)] \quad ...(1)$$

- Simple Harmonic Motion

$$y = (h/2) \times [1 - \cos(\pi\theta/\beta)] \quad ...(2)$$

- Constant Velocity

$$y = h\theta/\beta \quad ...(3)$$

- Constant Acceleration and Retardation

$$y = 2h \times (\theta/\beta)^2, \text{ for } \theta \leq (\beta/2) \quad ...(4)$$

$$y = h[1 - 2 \times \{1 - (\theta/\beta)\}^2] \quad ...(5)$$

for $\theta \leq (\beta/2)$

Where,

h = Lift of the follower,

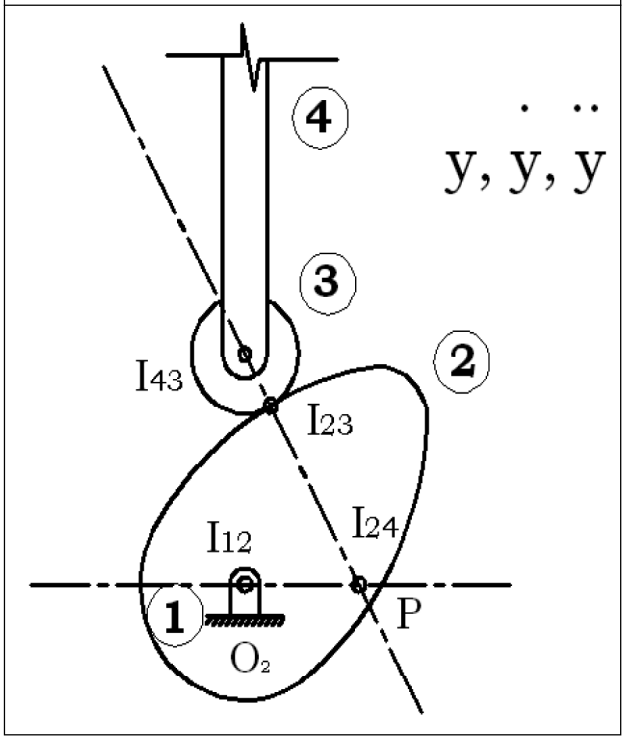
θ = Angular displacement of cam,

β = Angle of rise,

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,

$$v_p = \dot{y} = \omega_2 \times O_2P \quad ...(6)$$

$$O_2P = (\dot{y} / \omega_2) \quad ...(7)$$

$$T_2 = F_{32}^{Y} \times O_2P \quad ...(8)$$

$$F_{32}^{Y} = P + F_S + (-m\ddot{y}) \quad ...(9)$$

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 link 2,

m = Mass of follower,

F_s = Spring force,

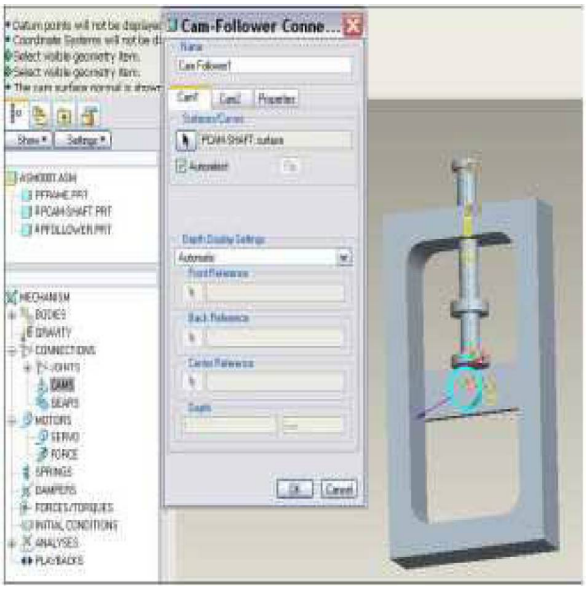
P = Force due to load.

SIMULATION

Simulation Procedure Using Simulation Software

Simulation of Cam and Follower mechanism simulation can be done using most recent simulation software, here in this paper attempt is made to carry out simulation using Pro-Engineering simulation module called Pro-Mechanica (Figure 3).

Figure 3: Cam Connection in Simulation



Simulation Connection

Case: I Servo Motor at Variable Speed.

- Open assembly mode into mechanism.
- First of all select new cam-connection from connection.
- Select cam surface in cam 1.
- Select cam 2 in dialog box.

Figure 4: Follower Connection in Simulation

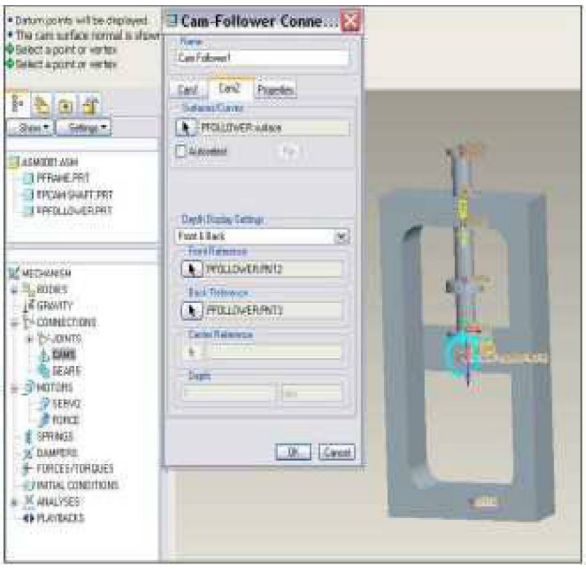
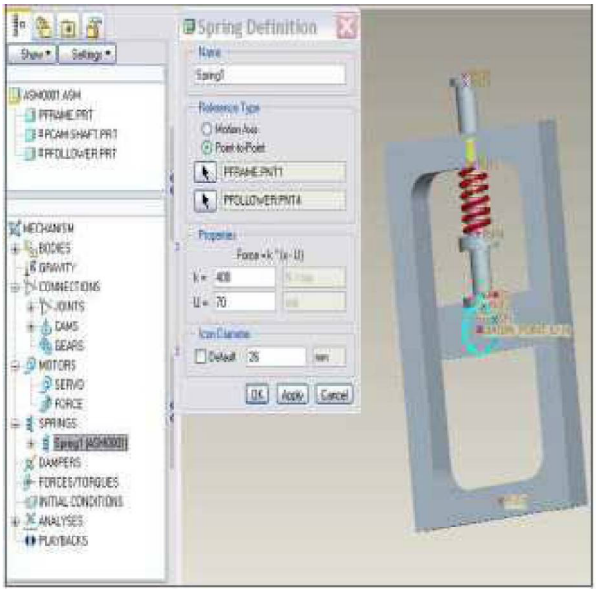


Figure 5: Considering Follower Gravity Force (9810 mm/sec²)



- Select the follower surface.
- Front and Back reference require flat face follower.
- From front reference select point on follower surface which is connected to cam.
- For back reference select point on back surface of follower.

Figure 6: Considering Spring Specifications

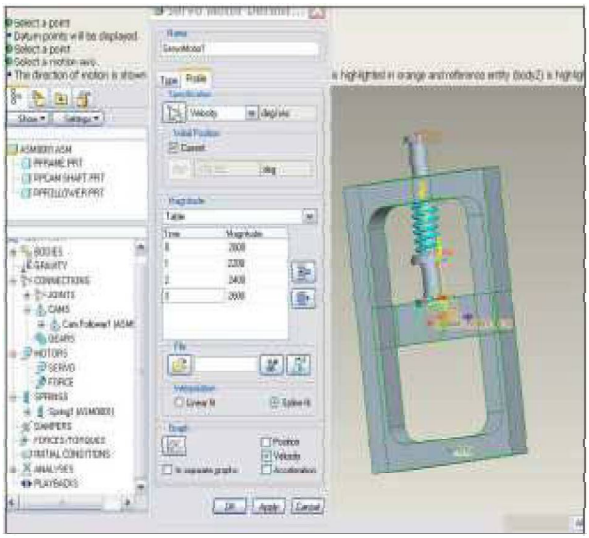
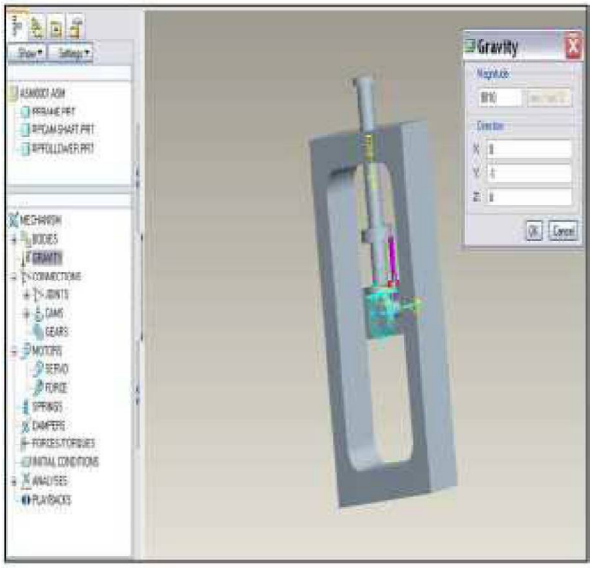
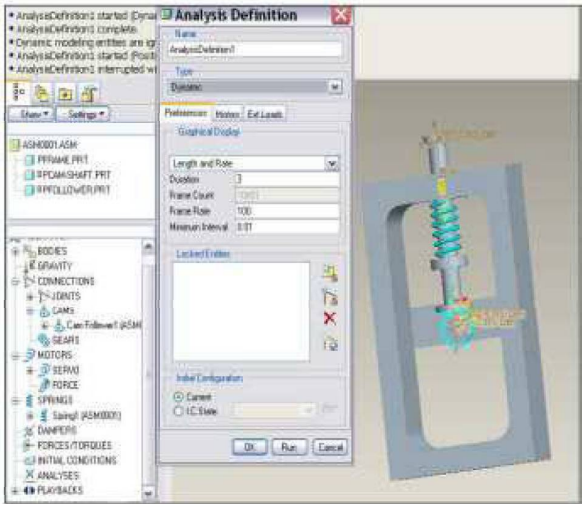


Figure 7: Servo-Motor at Variable Speed



- Select servo motor from motor.
- In specification of velocity, insert velocity with time table gradually increase.
- Select Mechanism analysis.
- Take Dynamic type and take duration up to the last time in the servo-motor table.
- Run the model and graph will be created.

Figure 8: Mechanism Analysis



RESULTS AND DISCUSSION

Kinematic Result

The results computed from the program developed for kinematic analysis of the follower are given for each 100 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, for simple harmonic motion,

Considering

h = 0.018 m,

ω_2 = 62.83 rad/sec,

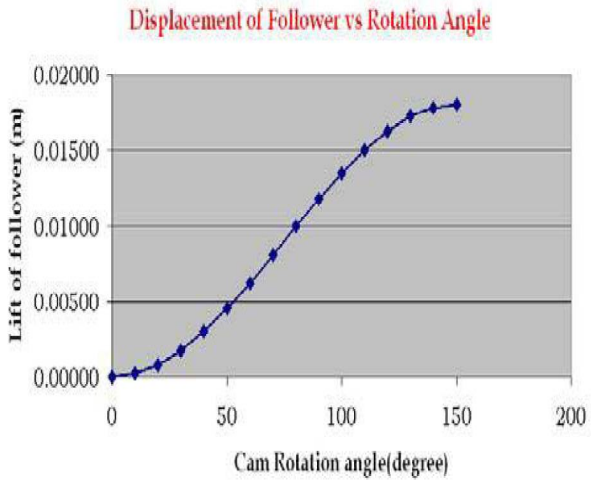
m = 1.6 kg,

and β = 150°

Table 1: Displacement, Velocity and Acceleration of Follower According to Cam Rotation Angle

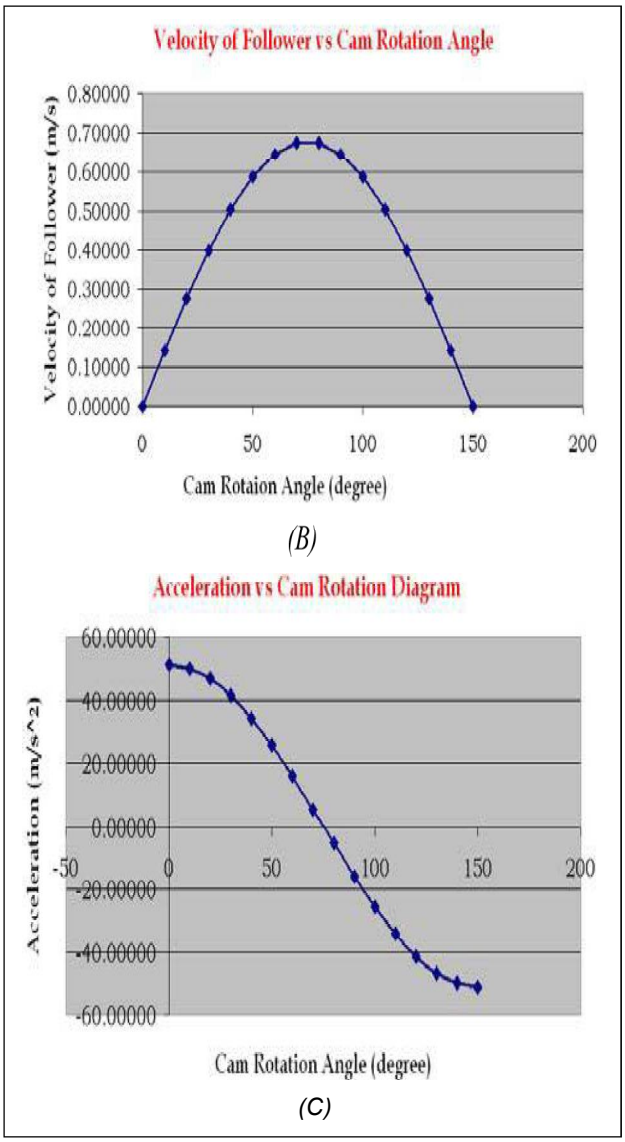
Angle of Rotation of Cam [θ]	Displacement of Follower m [y]	Velocity of Follower m/s [$\dot{y}$]	Acceleration of Follower m/s² [$\ddot{y}$]
0	0	0	51.16403
10	0.00020	0.14109	50.04597
20	0.00078	0.27600	46.74067
30	0.00172	0.39886	41.39257
40	0.00298	0.50429	34.23542
50	0.00450	0.58767	25.58201
60	0.00622	0.64537	15.81055
70	0.00806	0.67487	5.34810
80	0.00994	0.67487	–5.34810
90	0.01178	0.64537	–15.81055
100	0.01350	0.58767	–25.58201
110	0.01502	0.50429	–34.23542
120	0.01628	0.39886	–41.39257
130	0.01722	0.27600	–46.74067
140	0.01780	0.14109	–50.04597
150	0.01800	0.00000	–51.16403

Figure 9: (A)Displacement, (B) Velocity and (C) Acceleration of Follower According to Cam Rotation Angle



(A)

Figure 9 (Cont.)



(B)

(C)

Simulation Result

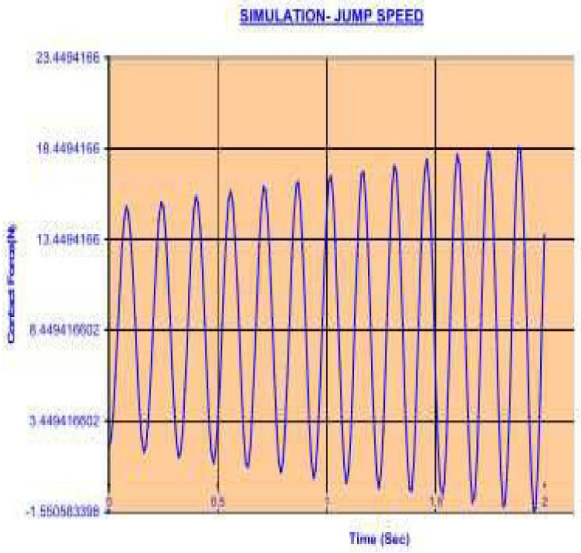
Case 1: Servo Motor at Variable Speed

Table 2: Motor at Variable Speed

Time	Deg/Sec
0	2200
1	2400
2	2600
3	2800

Figure 10 shows 1.05 sec connection force is zero and jump will being at speed of 402 rpm.

Figure 10: Jump Speed vs. Time



From the above graph we consider variation in jumping speed by simulation model. The reason behind it is that friction is not consider in simulation model. So more power is required in considering friction. So we need more power to overcome this friction so that speed is more.

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