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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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**
  \[ y = h\left[\frac{\theta}{\beta} - \frac{1}{2}\pi \times \sin \left(\frac{2\pi \theta}{\beta}\right)\right] \]  
  ...(1)

- **Simple Harmonic Motion**
  \[ y = \frac{h}{2} \times \left[1 - \cos \left(\frac{\pi \theta}{\beta}\right)\right] \]  
  ...(2)

- **Constant Velocity**
  \[ y = \frac{h \theta \beta}{\beta} \]  
  ...(3)

- **Constant Acceleration and Retardation**
  \[ y = 2h \times \left(\frac{\theta \beta}{2}\right)^2, \text{ for } \theta \leq \left(\frac{\beta}{2}\right)\]  
  ...(4)

  \[ y = h\left[1 - 2 \times \left\{1 - \left(\frac{\theta \beta}{2}\right)\right\}\right] \]  
  for \( \theta \leq \left(\frac{\beta}{2}\right) \)  
  ...(5)

Where,

- \( h \) = Lift of the follower,
- \( \theta \) = Angular displacement of cam,
- \( \beta \) = 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).
\[ \dot{y} = \text{Velocity of follower}, \]
\[ \ddot{y} = \text{Acceleration of the follower}, \]
\[ \omega_2 = \text{Angular velocity of cam}, \]
\[ T_2 = \text{Torque delivered to the cam}, \]
\[ F_{32} = \text{Reaction of link 3 on link 2}, \]
\[ m = \text{Mass of follower}, \]
\[ F_s = \text{Spring force}, \]
\[ P = \text{Force due to load}. \]

**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).

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

**Simulation Connection**

**Case:** I Servo Motor at Variable Speed.
• 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.

• 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.

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

\[ h = 0.018 \text{ m}, \]
\[ \omega_k = 62.83 \text{ rad/sec}, \]
\[ m = 1.6 \text{ kg}, \]
and \( \beta = 150^\circ \)
Table 1: Displacement, Velocity and Acceleration of Follower According to Cam Rotation Angle

<table>
<thead>
<tr>
<th>Angle of Rotation of Cam [θ]</th>
<th>Displacement of Follower m [y]</th>
<th>Velocity of Follower m/s [y']</th>
<th>Acceleration of Follower m/s² [y'']</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>51.16403</td>
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<td>10</td>
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<td>50.04597</td>
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<td>34.23542</td>
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<tr>
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<td>0.64537</td>
<td>15.81055</td>
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<td>0.67487</td>
<td>5.34810</td>
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<td>80</td>
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<td>−15.81055</td>
</tr>
<tr>
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<td>−25.58201</td>
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<td>0.00000</td>
<td>−51.16403</td>
</tr>
</tbody>
</table>

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

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

Table 2: Motor at Variable Speed

<table>
<thead>
<tr>
<th>Time</th>
<th>Deg/Sec</th>
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<tr>
<td>0</td>
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</tr>
<tr>
<td>1</td>
<td>2400</td>
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<tr>
<td>2</td>
<td>2600</td>
</tr>
<tr>
<td>3</td>
<td>2800</td>
</tr>
</tbody>
</table>

Simulation Result
Case 1: Servo Motor at Variable Speed
From the above graph we consider variation in jumping speed by simulation model. The reason behind it is that friction is not considered 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.

REFERENCES


