Kinematics and Dynamics of Machinery

Walking Beam Indexer Mechanism

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1 Team Members

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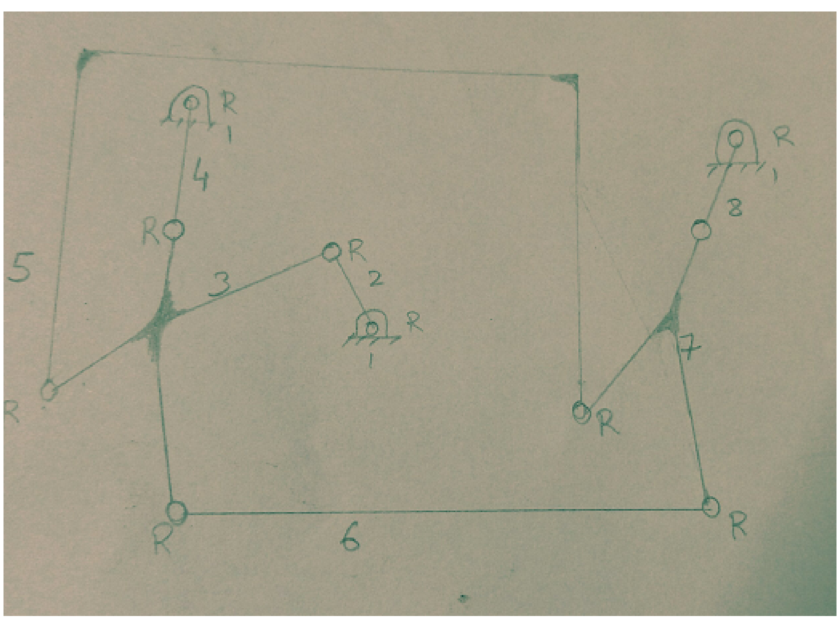
2 Introduction

In industries or plants where transport of products is required Walking Beam Mechanism is used. This mechanism is especially preferred over conveyor belt when the product is required to dwell for some time for indexing or packaging process and then needs to be moved.
The Kinematic Diagram of the mechanism is shown below:



From the diagram:

$$n = 8, j = 20$$

Hence the Degree of Freedom for the mechanism is:

$$3(n - 1) - j = 3(8 - 1) - 20 = 1$$

Hence the mechanism is a **constrained mechanism**.

3 Input Variables and Assumptions

3.1 Height of Installation

This is the height at which the rack carrying the product needs to be installed. This is denoted by letter H.

Assumption is $H = 16cm$

3.2 Quick Return Time Ratio:

During the halt time of the product, operations like indexing, packaging, etc. are performed. This halt time and time taken for pushing the product determines the time ratio of the mechanism.
The quick return time ratio is given by:

$$\frac{HaltTime}{PushTime}$$

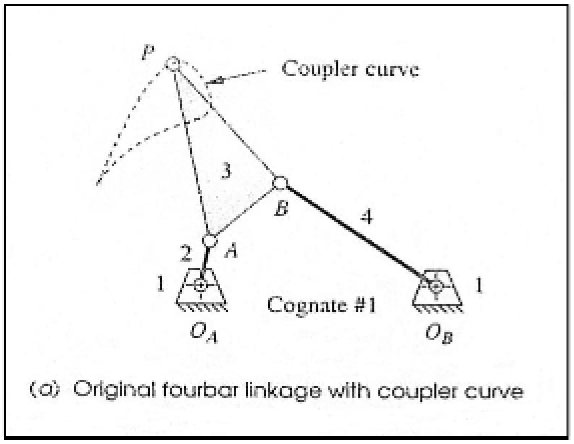
Assumption: $TimeRatio = 1$

3.3 Length of Beam

The length of beam depends on how many products need to be pushed forward at a time in one cycle of the motion.
Assumption: $LengthofBeam = 26cm$

3.4 Coupler Curve

In the mechanism there is a four bar loop having the coupler as quarternery link. The hinge connected to the beam is the output hinge. The meaning of output hinge is that the path generated by this hinge charecterises this mechanism.
The whole problem is basically path generation of this hinge and the curve generated by this is known as Coupler Curve. The basic four bar loop is shown below.

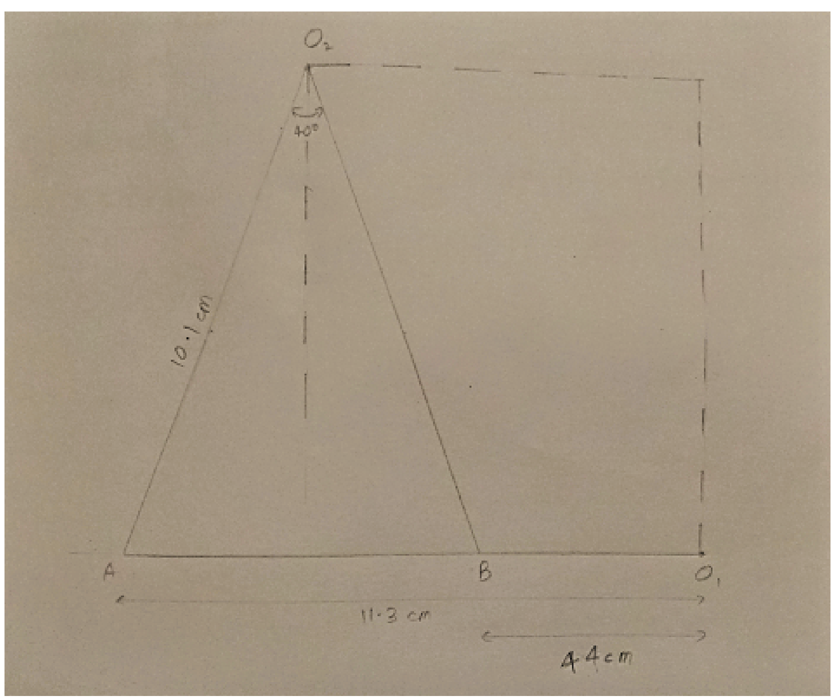


Graphical Synthesis:

Assumptions:

1. Quick Return time ratio = 1
2. Angle of sweep of rocker = 40^0
3. Position of fixed hinges:
   (a) Co-ordinates of crank fixed hinge = (0,0)
   (b) Co-ordinates of rocker fixed hinge = (7.9cm, 9.6cm) (This was assumed on the basis of height of installation of mechanism)

With the above assumptions the mechanism was graphically synthesized as shown below.



From the synthesis if l_1 is crank length and l_2 is coupler length then :

$$l_1 + l_2 = 11.3cm$$
$$l_1 - l_2 = 4.4cm$$
$$\implies l_1 = 3.45cm$$
$$\implies l_2 = 7.85cm$$

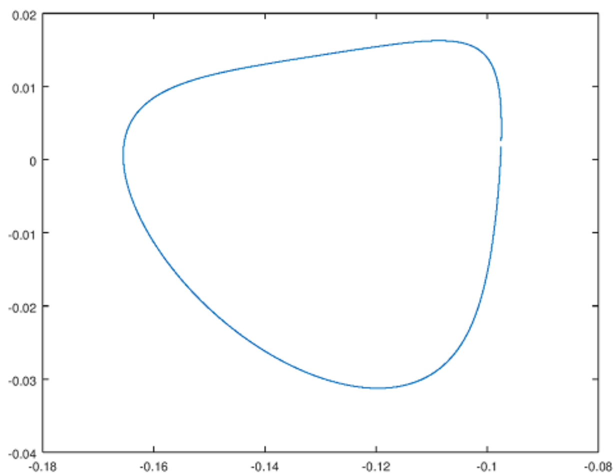
The dimensions of the ternary link is assumed based on following:

1. Push distance was assumed to be 8cm.
2. The height of the beam to be 10cm.

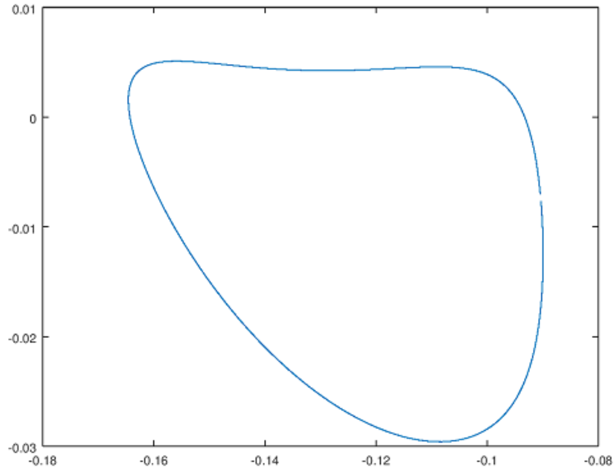
The dimensions of the link are:

$$l5 = 12.8cm, a = 12^0$$

After this synthesis matlab code was written to plot the coupler curve which generated a coupler curve as given below:



But according to this coupler curve the beam does not move in a horizontal line but rather in a slant line during pushing of the product.
So the lengths were changed without changing the assumed values of input variables. Finally a coupler curve was got as shown below:

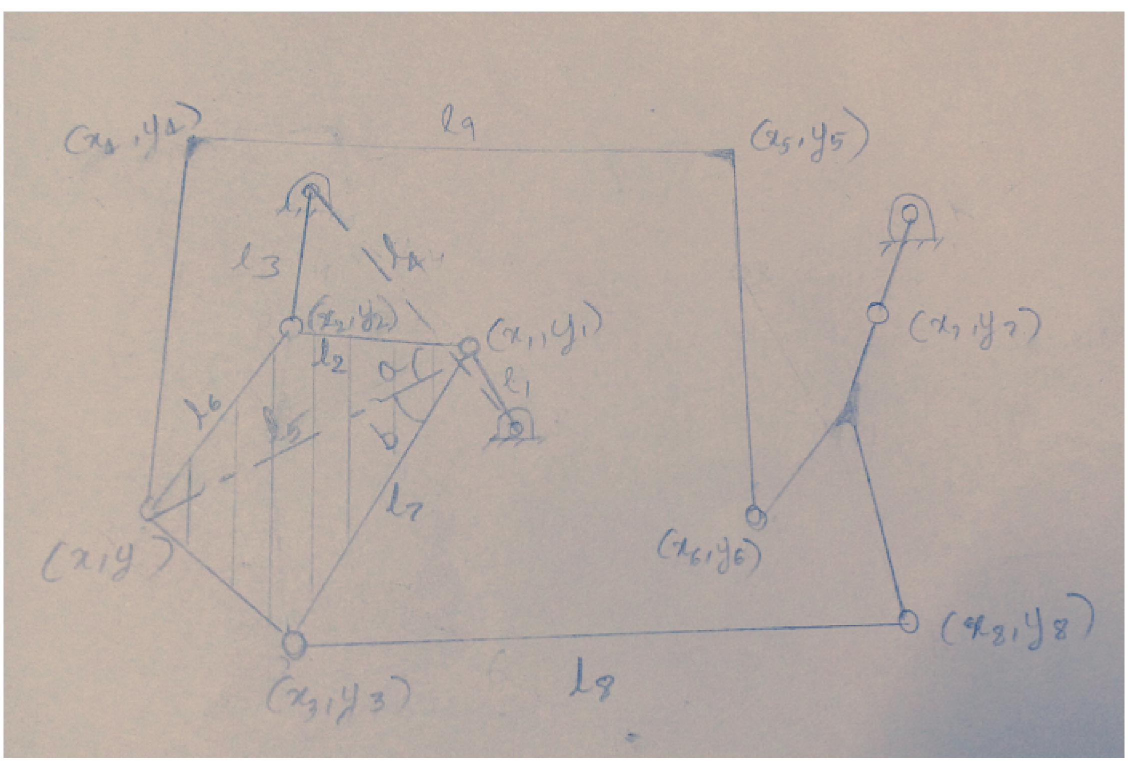


Hence from this plot the beam follows almost a straight line while it pushes the product.

4 Code

1. **Link Labels:**

   The link lengths and angles are labeled as shown in the figure below and these lables are used in the code.



2. **Kinematic Analysis:**

   Kinematic analysis is done for the basic four bar loop with ternary link as coupler and not for the whole mechanism. The whole idea of the analysis was to find the coupler curve, find the push distance of the beam, plot angular velocities and accelerations of coupler and rocker with angle of rotation of crank.
   From the diagram by loop closure method:

$$\vec{l_1} + \vec{l_2} + \vec{l_3} = \vec{l_4}$$
$$l_1cos\theta_1 + l_2cos\theta_2 + l_3cos\theta_3 = l_4cos\theta_4$$
$$l_1sin\theta_1 + l_2sin\theta_2 + l_3sin\theta_3 = l_4sin\theta_4$$

   Solving the above equation for θ_2 and θ_3 we get:

$$A = l_1cos\theta_1 - l_4cos\theta_4$$
$$B = l_1sin\theta_1 - l_4sin\theta_4$$

$$C = \frac{l_3^2 - l_4^2 - l_2^2 - l_1^2 + 2l_1l_4cos(\theta_1 + \theta_4)}{2l_2}$$
$$C_1 = \frac{l_2^2 - l_4^2 - l_3^2 - l_1^2 + 2l_1l_4cos(\theta_1 + \theta_4)}{2l_3}$$
$$x = \frac{B - \sqrt{A^2 + B^2 - C^2}}{A + C}$$
$$x_1 = \frac{B - \sqrt{A^2 + B^2 - C_1^2}}{A + C_1}$$
$$\theta_2 = 2tan^{-1}(x)$$
$$\theta_3 = 2tan^{-1}(x_1)$$

   The values of θ_2 and θ_3 will exceed more than 90^0. Hence approriate angles are added to correct this as shown in the code.
   For Velocity and Acceleration analysis Newton-Raphson metod was used whose jacobian is given below.

$$J = \begin{bmatrix} l_2sin\theta_2 & l_3sin\theta_3 \\ l_2cos\theta_2 & l_3cos\theta_3 \end{bmatrix}$$

3. **Coupler Curve**

   The coupler curve co-ordinates are:

$$x = l_1cos\theta_1 + l_5cos(a + \theta_2)$$
$$y = l_1sin\theta_1 + l_5sin(a + \theta_2)$$

4. **Animation**

   Animation is made using *plot()* function. For animation the co-ordinates of each hinges where found taking the crank fixed hinge as origin.