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Research Paper

COMPUTER AIDED MODELLING AND POSITION ANALYSIS OF CRANK AND SLOTTED LEVER MECHANISM

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The paper is discussed about crank and slotted mechanism that converts rotary motion into reciprocating motion at different rate for its two strokes, i.e., working stroke and return stroke. Time ratio has been calculated for constant length of stroke with specified dimensions. A CAD model has been prepared to simulate the mechanism and to specify the accurate path of the mechanism. Also the analytical method which can be used to define the various position of crank and respective position of slider in quick return mechanism is discussed.

Keywords: Quick return mechanism, CAD model, Position analysis

INTRODUCTION

A quick return mechanism is a mechanism that converts rotary motion into reciprocating motion at different rate for its two strokes, i.e., working stroke and return stroke. When the time required for the working stroke is greater than that of the return stroke, it is a quick return mechanism. It yields a significant improvement in machining productivity. Currently, it is widely used in machine tools, for instance, shaping machines, power-driven saws, and other applications requiring a working stroke with intensive loading, and a return stroke with non-intensive loading. Several quick return mechanisms can be found including the offset crank slider mechanism, the crank-shaper mechanisms, the double crank mechanisms, crank rocker mechanism and Whitworth mechanism. In mechanical design, the designer often has need of a linkage that provides a certain type of motion for the application in designing. Since linkages are the basic building blocks of almost all mechanisms, it is very important to understand how to design linkages for specific design characteristics. Therefore, the purpose of this project is to synthesize quick-return mechanism that converts rotational to translational motion.

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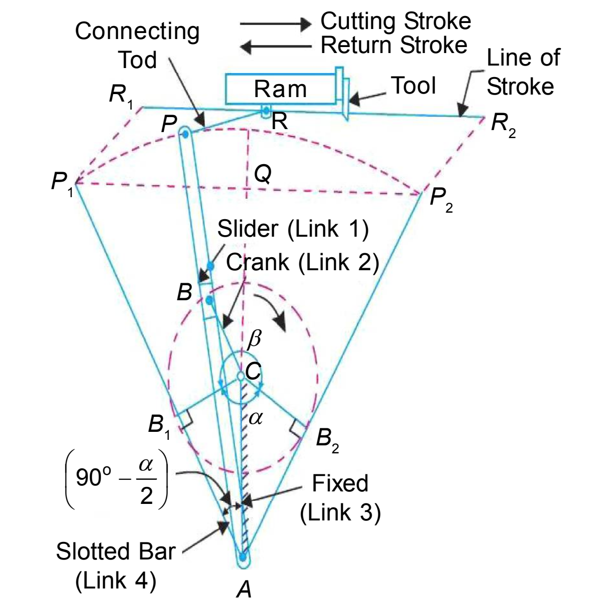
Crank and Slotted Lever Quick Return Mechanism

This mechanism is mostly used in shaping machines, slotting machines and in rotary internal combustion engines. In this mechanism, the link *AC* (i.e., link 3) forming the turning pair is fixed, as shown in Figure 1. The link 3 corresponds to the connecting rod of a reciprocating steam engine. The driving crank *CB* revolves with uniform angular speed about the fixed centre *C*. *A* sliding block is attached to the crank pin at *B* slides along the slotted bar *AP* and thus causes AP to oscillate about the pivoted point *A*. *A* short link *PR* transmits the motion from AP to the ram which carries the tool and reciprocates along the line of stroke R_1R_2. The line of stroke of the ram (i.e., R_1R_2) is perpendicular to *AC* produced. In the extreme positions, AP_1 and AP_2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB_1 to CB_2 (or through an angle β) in the clockwise direction. The return stroke occurs when the crank rotates from the position CB_2 to CB_1 (or through angle α) in the clockwise direction.

Figure 1: Crank and Slotted Lever Quick Return Motion Mechanism



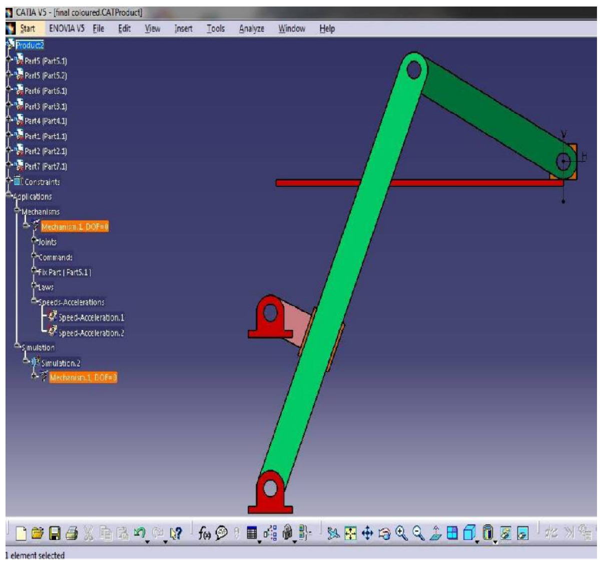
COMPUTER AIDED MODELLING OF CRANK AND SLOTTED LEVER QUICK RETURN MECHANISM

Data required for modeling of crank slotted mechanism is given in Table 1. Modeling has been prepared in CATIA V5R17 (Figure 2). Dimensions of the mechanism given in the table are useful to calculate length of stroke and time ratio.

Table 1: Dimensions of Links of Crank Slotted Mechanism

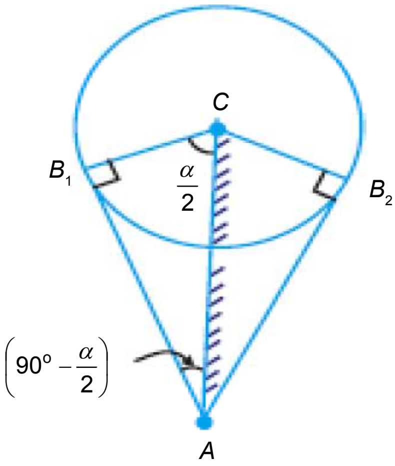
S. No.	Links	Diamensions
1.	Crank	100 mm
2.	Distance Between Pivots	250 mm
3.	Slotted Bar	650 mm

Figure 2: CAD Model of Crank Slotted Mechanism



DETERMINATION OF LENGTH OF STROE AND TIME RATIO

Let $\angle CAB_1$ = Inclination of the slotted bar with the vertical.



We know that

$$\sin\angle CAB_1 = \sin\left(90^\circ - \frac{\alpha}{2}\right)$$

$$= \frac{B_1C}{AC} = \frac{100}{250} = 0.4$$

$$\angle CAB_1 = \left(90^\circ - \frac{\alpha}{2}\right) = 23.58^\circ$$

Again,

$$\angle CAB_1 = \left(90^\circ - \frac{\alpha}{2}\right)$$

α = 132.84°

$$Time\ Ratio = \frac{Time\ of\ Cutting\ Stroke}{Time\ of\ Return\ Stroke}$$

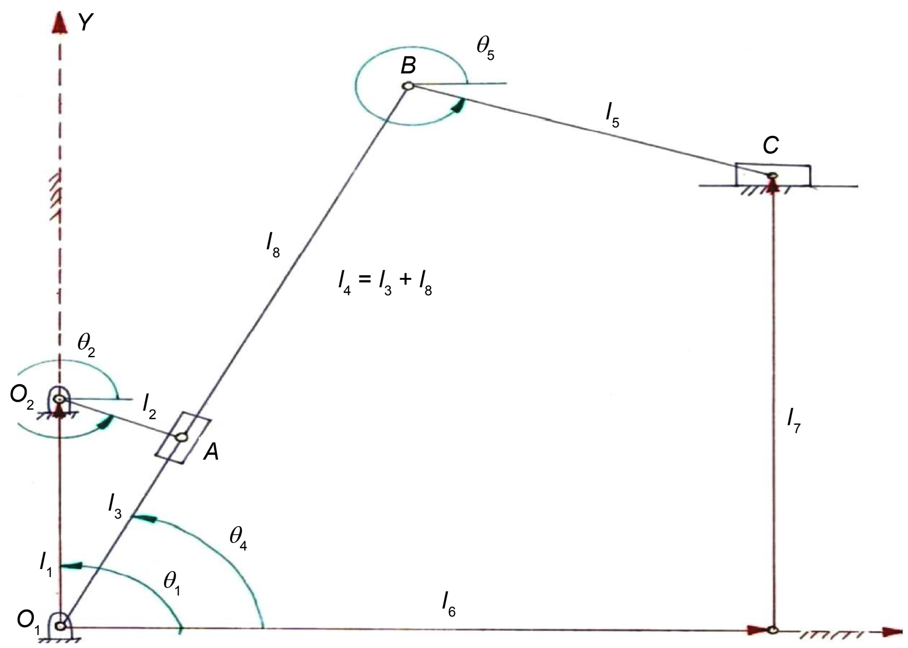
$$= \frac{360 - \alpha}{\alpha} = 1.71$$

Length of Stroke = $R_1R_2 = P_1P_2 = 2P_1Q$

$$= 2AP_1 \sin\left(90^\circ - \frac{\alpha}{2}\right) = 520 \text{ mm}$$

Looking at Figure 3 the crank and slotted lever quick return mechanism can be broken up into multiple vectors and two loops. Utilizing

Figure 3: Vector Representation of Crank and Slotted Lever Quick Return Mechanism



these two loops, the following sections will go through the kinematic analysis of the Crank and slotted lever Quick Return Mechanism.

POSITION ANALYSIS

For the Crank and slotted lever Quick Return Mechanism shown in Figure 3, the displacement analysis can be formulated by the following loop-closer equations

$$l_1 + l_2 = l_3 \quad ...(1)$$

$$l_3 + l_8 + l_5 = l_6 + l_7 \quad ...(2)$$

Using complex numbers, Equations (1 and 2) become

$$l_1 e^{i\theta 1} + l_2 e^{i\theta 2} = l_3 e^{i\theta 3} \quad ...(3)$$

$$l_3 e^{i\theta 3} + l_8 e^{i\theta 8} + l_5 e^{i\theta 5} = l_6 e^{i\theta 6} + l_7 e^{i\theta 7} \quad ...(4)$$

where the link lengths l_1, l_2, l_5, l_7 and angular positions θ_1, θ_6 and θ_7 are constants. Angular position θ_2 is an independent variable; angular positions θ_3, θ_8, θ_4 and θ_5 are dependent variables.

From figure $\theta_8 = \theta_3 = \theta_4$ and $l_4 = l_3 + l_8$

Substituting and rearranging Equations (1 and 2);

$$l_3 e^{i\theta 4} = l_1 e^{i\theta 1} + l_2 e^{i\theta 2} \quad ...(5)$$

$$l_4 e^{i\theta 4} + l_5 e^{i\theta 5} + l_6 e^{i\theta 6} = l_7 e^{i\theta 7} \quad ...(6)$$

As Equation (5) has 2 unknowns and Equation (6) has 3 unknowns,

Utilizing Euler's equation, $e^{i\theta} = \cos\theta + i\sin\theta$

$l_3\cos\theta_4 + i\sin\theta_4 = l_1\cos\theta_1 + i\sin\theta_1 + l_2\cos\theta_2 + i\sin\theta_2$

Separate this equation in real numbers and imaginary numbers.

$$l_3\cos\theta_4 = l_1\cos\theta_1 + l_2\cos\theta_2 \quad ...(7)$$

$$l_3\sin\theta_4 = l_1\sin\theta_1 + l_2\sin\theta_2 \quad ...(8)$$

Squaring Equations (7 and 8) and adding them together;

$$l_3 = \sqrt{(l_1\cos\theta_1 + l_2\cos\theta_2)^2 + (l_1\sin\theta_1 + l_2\sin\theta_2)^2} \quad ...(9)$$

Dividing Equation (8) by Equation (7) and simplifying gives

$$\theta_4 = \tan^{-1}\left(\frac{(l_1\sin\theta_1 + l_2\sin\theta_2)}{(l_1\cos\theta_1 + l_2\cos\theta_2)}\right) \quad ...(10)$$

By knowing the value of θ_4, Equation (6) has only 2 unknown values,

$$l_6 e^{i\theta 6} - l_5 e^{i\theta 5} = l_4 e^{i\theta 4} - l_7 e^{i\theta 7} \quad ...(11)$$

Since right hand side of Equation (11) is constant

Let,

$le^{i\theta} = l_4 e^{i\theta 4} - l_7 e^{i\theta 7}$

Now Equation (11) becomes,

$$l_6 e^{i\theta 6} - l_5 e^{i\theta 5}5 = le^{i\theta} \quad ...(12)$$

Again break the equation into real and imaginary part,

$$l_6\cos\theta_6 - l_5\cos\theta_5 = l\cos\theta \quad ...(13)$$

$$l_6\sin\theta_6 - l_5\sin\theta_5 = l\sin\theta \quad ...(14)$$

By solving Equations (13 and 14),

$$l_6 = \left(\frac{l\cos\theta + l_5\cos\theta_5}{\cos\theta_6}\right) \quad ...(15)$$

$$l_6 = \left(\frac{l\sin\theta + l_5\sin\theta_5}{\sin\theta_6}\right) \quad ...(16)$$

Where Equation (15) is used when $\cos\theta_6 > 0$ and Equation (16) is used when $\cos\theta_6 = 0$

Put Equation (15) in Equation (14)

$$\left(\frac{l\cos\theta + l_5\cos\theta_5}{\cos\theta_6}\right)\times\sin\theta_6 - l_5\sin\theta_5 = l\sin\theta$$

$$\sin(\theta_5 - \theta_6) = \frac{l\cos\theta\sin\theta_6 - l\sin\theta\cos\theta_6}{l_5} \quad ...(17)$$

Solving for θ_5, we get

$$\theta_{5a} = \theta_6 + \sin^{-1}\left(\frac{l\cos\theta\sin\theta_6 - l\sin\theta\cos\theta_6}{l_5}\right) \quad ...(18)$$

$$\theta_{5b} = \theta_6 + \pi - \sin^{-1}\left(\frac{l\cos\theta\sin\theta_6 - l\cos\theta\sin\theta_6}{l_5}\right) \quad ...(19)$$

By knowing all of the angular positions and the length of l_6, we can find the position of the output slider C by using

$$P_c = l_4 + l_5 \quad ...(20)$$

CONCLUSION

From the given dimensions of links of the quick return mechanism, time ratio has been calculated which is equal to 1.71 for constant stroke length of 520 mm. This approach will help designer to synthesize the quick return mechanism for desired stroke length.

REFERENCES

1. Harry H Cheng (2004), "Computer-Aided Mechanism Design", *Journal of Mechanical Engineering Science*, Vol. 220, March 14.
2. Matt Campbell and Stephen S Nestinger (2004), "Computer-Aided Design and Analysis of the Whitworth Quick Return Mechanism", Department of Mechanical and Aeronautical Engineering, University of California Davis, CA.
3. Ron P Podhorodeski, Scott B Nokleby and Jonathan D Wittchen (2004), "Quick-Return Mechanism Design and Analysis Projects", *International Journal of Mechanical Engineering Education*, Vol. 32, No. 2, pp. 100-114.
4. Wen-Hsiang Hsieh and Chia-Heng Tsai (2009), "A Study on a Novel Quick Return Mechanism", CSME-13, E.I.C. Accession 3051, Vol. 08.