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Kinematic Analysis and Simulation of Crank and Slotted Quick Return Mechanism

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***Abstract*—Machines reduce effort and complete tasks efficiently. They generate movement through a specific mechanism. In workshops, machines like shaper machines utilize the quick return mechanism. This mechanism consists of a combination of cranks and sliders that convert rotational motion into reciprocating motion. The objective of this report is to demonstrate the quick return mechanism through the development of a digital model and examination of its motion characteristics. By determining the velocity, acceleration, and displacement produced by the slider, we can draw conclusions about the mechanism's application in industrial settings. Additionally, this mechanism can serve as a cost-effective alternative to expensive automated machines commonly used in packaging industries.**

Keywords—quick return mechanism, solidworks, and simulation.

I. INTRODUCTION

When a link within a kinematic chain is immobilized, the chain transforms into a mechanism. A machine, on the other hand, is constituted by either a single mechanism or a blend of mechanisms. Beyond merely directing specific movements to its components, a machine also transmits and alters the existing mechanical energy to accomplish desired tasks. A quick return mechanism specifically converts circular motion into back-and-forth motion, operating at distinct speeds for its two strokes: the working stroke and the return stroke.This project is all about understanding how the mechanism moves and behaves using simulation software like Solidworks. By studying the kinematics and dynamics of the mechanism, we will be able to get a better idea of how it performs, its efficiency, and where there might be room for improvement.

A. Objective

1. To examine the movement of the crank and slotted quick return mechanism.
2. To calculate the speed of movement for each link within the mechanism.
3. To ascertain the rate of change of velocity for each link within the mechanism.

B. Problem statement

The objective of this project is to examine and replicate the movement of a crank and slotted quick return mechanism. Through a motion analysis conducted in SolidWorks, our goal is to grasp the kinematics and dynamics of the mechanism, encompassing its motion, velocities, and accelerations. This evaluation will enable us to assess its performance. efficiency, and potential areas for improvement of the mechanism.

C. Methodology

To analysis of quick return mechanism, the 3D model was designed with proper dimension and motion study is also carried out in solidworks and result of simulation is plotted in the form graph.

II. LITERATURE SURVEY

Matt Campbell and Stephen S. Nestinger researched a specialized software package designed specifically for analyzing and designing Whitworth Quick Return Mechanisms. The Quick Return category can be utilized to compute or visualize the location, speed, and The rate at which the mechanism's motion changes over time.
Rupanshu Singh illustrates the Whitworth mechanism through the creation of a digital model and scrutiny of its motion. The speed, acceleration, and force produced by the slider are assessed, and a conclusion is drawn regarding the mechanism's suitability for industrial applications. Additionally, consideration is given to its potential as a cost-effective alternative to expensive automated packaging machinery in industrial settings.
Katarina Monkova employed three techniques to analyze the kinematics of the Quick Return mechanism. Following the evaluation, the author determined that computer-aided methods are both more precise and quicker in comparison to the alternatives.
Chao Zgang examined the rotational behavior of The guide-bar assembly and slider-crank setup within Advanced or sophisticated research facilities. An initial Model or sample was generated for modeling, followed by an analysis of kinematics encompassing displacement, velocity, and acceleration of the original moving component and the output member link. The investigation then shifted towards studying the kinetic analysis of the main components.

III. THEORY

A. Construction

The crank and slotted lever quick return mechanism is a type of mechanical linkage designed to transform rotational movement into linear back-and-forth motion. This mechanism comprises three essential components: a crank, a slotted lever, and a connecting rod.
1. Crank: A rotating lever, typically driven by a motor or manual input, that converts rotary motion into oscillating motion.
2. Connecting Rod: Links the crank to the slotted lever, transmitting motion between them.

3. Slotted link: A lever with a slot or groove that holds a sliding block attached to the connecting rod. The slotted lever constrains the motion of the block, causing it to reciprocate.

B. Working Principle:

As the crank turns, it transfers alternating motion to the connecting rod.The connecting rod, in turn, drives the sliding block along the slot in the slotted lever. The sliding block's motion causes the slotted lever to oscillate, producing a reciprocating output at the opposite end of the mechanism.The quick return is a characteristic feature of this mechanism.During one half of the cycle, the reciprocating motion of the slotted lever is faster (the quick motion). During the other half, it returns more slowly (the return motion).This is achieved by adjusting the lengths of the crank and the connecting rod.

This mechanism is predominantly utilized in shaping machines, slotting machines, and rotary internal combustion engines.

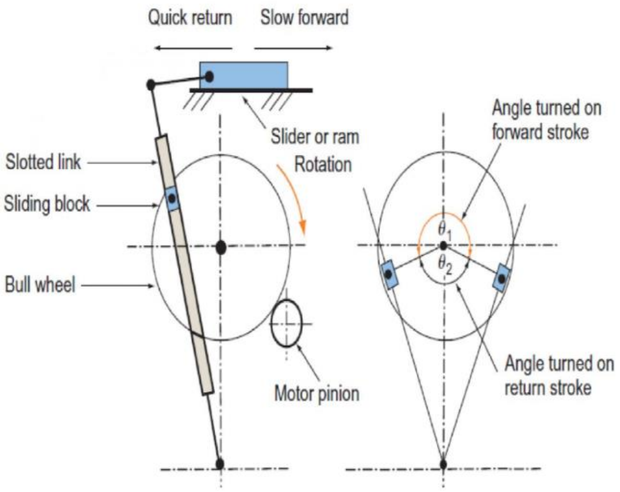

Fig. Crank and Slotted quick return mechanism

C. Time and Length of Stroke

In this setup, the link AC (referred to as Link 3) acts as a fixed turning pair, as depicted in the diagram. Link 3 serves as the connecting rod in a quick return mechanism. The crank CB rotates steadily at a constant angular velocity around the stationary center C. Attached to the crankpin at B, a slider moves along the slotted bar AP, causing AP to pivot about point A. The motion is then transferred from AP to the ram via a shorter link PR, which houses the tool and moves back and forth along the stroke line R1R2. The The stroke line of the ram, identified as R1 and R2, extends at a right angle to the prolonged line of AC.

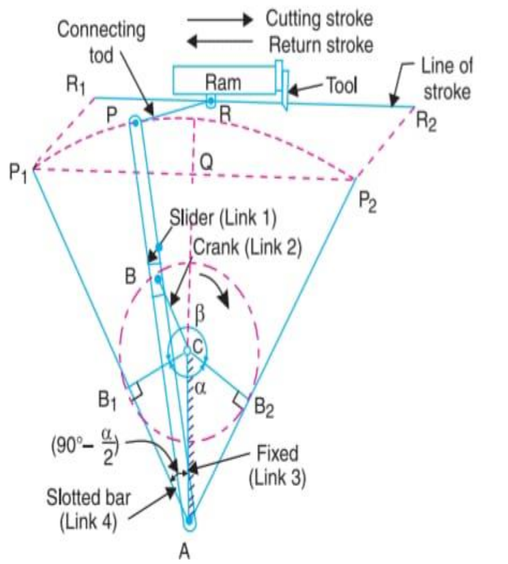

Fig. Crank and slotted lever quick return motion mechanism

At the farthest points, AP1 and AP2 align tangentially with The circle denotes the location of the cutting implement at the conclusion of the stroke. The forward, or cutting stroke, occurs when the crank transitions From the initial position CB1 to the final position CB2. rotating clockwise through an angle ß. On the contrary, The return stroke happens as the crank turns in a clockwise direction, moving from CB2 to CB1 completing an angular motion in the opposite direction. This rotation occurs uniformly due to the constant angular speed of the crank. therefore,

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360° - \beta} \quad \text{or} \quad \frac{360° - \alpha}{\alpha}$$

Since the tool covers a distance from R1 to R2 during both the cutting and return strokes, the overall distance traveled by the tool, known as the stroke length,

$$= R_1R_2 = P_1P_2 = 2P_1Q = 2AP_1 \sin \angle P_1AQ$$

$$= 2AP_1 \sin\left(90° - \frac{\alpha}{2}\right) = 2AP \cos\frac{\alpha}{2} \qquad \ldots\ldots (\because AP_1 = AP)$$

$$= 2AP \times \frac{CB_1}{AC} \qquad \ldots \left(\because \cos\frac{\alpha}{2} = \frac{CB_1}{AC}\right)$$

$$= 2AP \times \frac{CB}{AC} \qquad \ldots (\because CB_1 = CB)$$

IV. SOFTWARE REQUIREMENT

For this project we will use solidworks software for modeling and motion study feature in the solidworks for simulation.

A. Solidworks

The SolidWorks CAD software is a tool for mechanical design automation, enabling designers to swiftly conceptualize ideas, test various features and measurements, and generate detailed models and drawings.

B. Solidworks Motion Study

Motion studies in SOLIDWORKS involve creating graphical simulations of motion for assembly models. These simulations allow us to incorporate visual elements like

lighting and camera perspectives while animating prescribed motions. Solidworks mates play a crucial role in restricting component motions within the assembly.
Three basic tools available in the solidworks motion study,

1.Animation
Animation in core SOLIDWORKS to bring assemblies to life through motion.Integrate motors to drive specific parts within the assembly, and establish key points to dictate component positions at different times. Animation employs interpolation to smoothly define the motion of assembly components between these key points, allowing for dynamic and visually engaging simulations of the assembly's motion.

2.Basic Motion
Basic Motion in solidworks to approximate the impact of motors, springs, contact, and gravity on assemblies. This feature considers mass in motion calculations, allowing for quick and efficient physics-based simulations. Basic Motion is ideal for generating visually appealing animations that showcase the dynamic effects within an assembly, making it suitable for creating presentations and animations with a focus on realism.

3.Motion Analysis
Motion Analysis, an advanced feature available with the solidworks Motion add-in to solidworks Premium, for precise simulation and analysis of motion effects on assemblies.This tool incorporates robust kinematic solvers, factoring in various motion elements such as forces, springs, dampers, and friction. Motion Analysis goes beyond basic simulations, considering material properties, mass, and inertia in its computations. Additionally, it allows for result plotting, enabling in-depth analysis and a comprehensive understanding of the assembly's dynamic behavior.

V. MODELING

A 3D model of Crank andslotted quick return mechanismwas designed in Solidworks 2019 to analyze the motion generated by the Crank and Slotted Quick Return Mechanism as shown in Figure. Different parts like cranks, sliders, slotted lever and connecting rod were designed in the Solidworks 2019 with accurate dimension. All this 3D was assembled in solidworks 2019 with proper constraint by using assembly feature. The connections of joints and sliders were defined to obtain the motion of the mechanism. Dimension of each link is as follow,

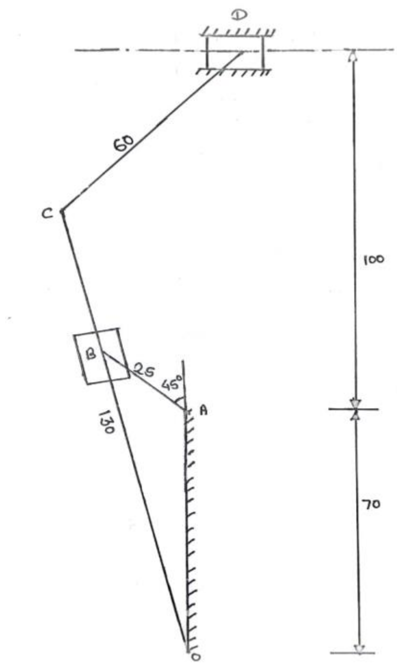

Fig. Crank and slotted quick return mechanism

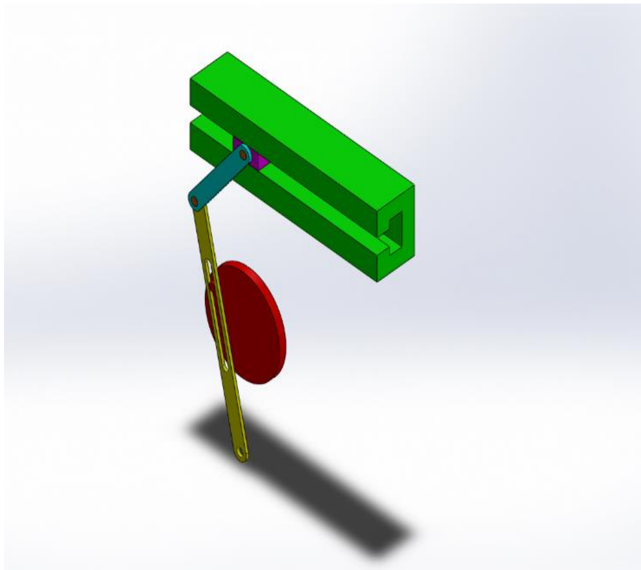

Fig.3D model of crank and slotted quick return mechanism

VI. SIMULATION

Simulation of Crank and Slotted quick return mechanism is done in solidworks 2019 by using the motion study feature. The motion in solidworks will help to analyze the motion of mechanism, velocity and force, by adding mates and constraints, setting up initial conditions and external influences motion of mechanism can easily simulate. For the motion study of crank and slotted quick return mechanism the cranks are rotated by motor at 100 rpm and the relative motion of slider is observed. The movement of the mechanism in complete cycle forward and backward stroke is obtained. The motion of model was analyzed in solidworks 2019 and plot of acceleration, velocity, displacement for each link is plotted. The simulation of quick return mechanism is as shown in the following figure.

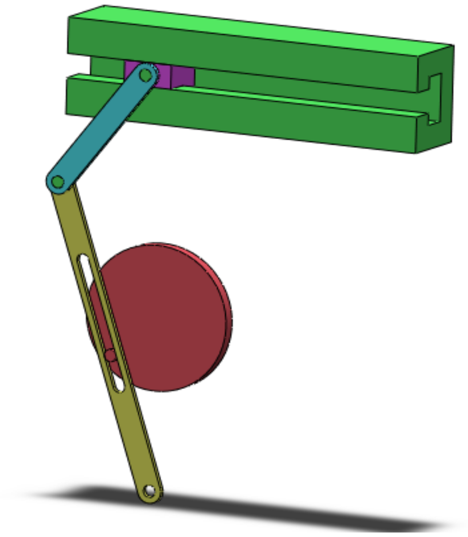

Fig. Simulation of quick return mechanism

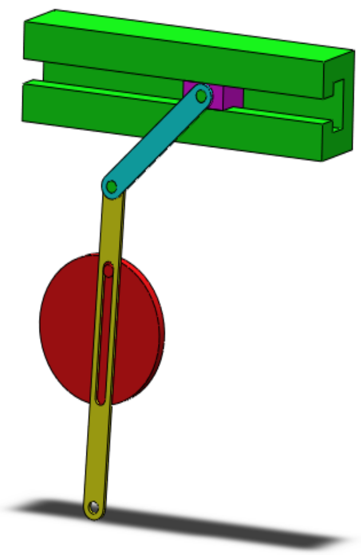

Fig. Simulation of quick return mechanism

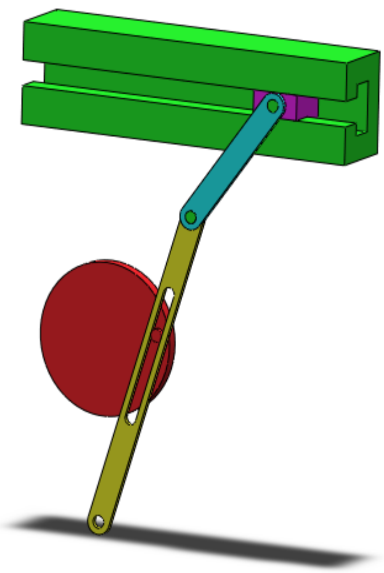

Fig. Simulation of quick return mechanism

VII. Calculations

A. Length of Stroke

Length of Stroke is given by,

$2AP \times \frac{CB}{AC}$

=2*130*25/72
=90.27

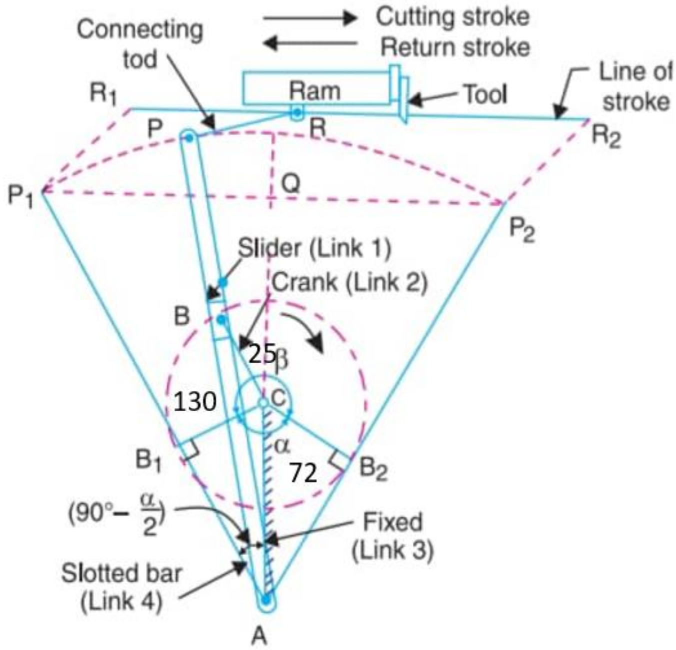

Fig. quick return mechanism

B. Velocity During Cutting Stoke

Maximum Velocity During Cutting Stoke is given by,

= ω*OB*AC/(AB$_3$)

=(2*π*N/60)*OB*AC/(AO+OB)

=(2*π*100/60)*25*130/(70+25)

=358.25 mm /Sec

C. Velocity During Return Stoke

Maximum Velocity During Cutting Stoke is given by,

= ω*OB*AC/(AB$_4$)

=(2*π*N/60)*OB*AC/(AO-OB)

=(2*π*100/60)*25*130/(70-25)

=756.30 mm /Sec

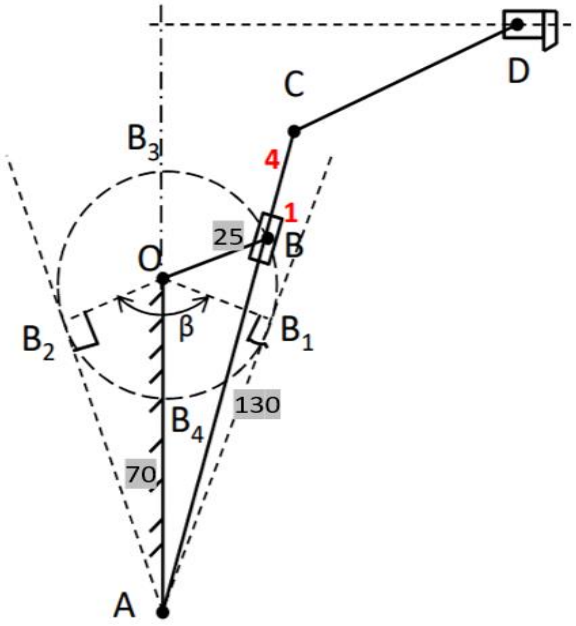

Fig. quick return mechanism

Maximum stoke length and maximum velocity is calculated by analytical method maximum stoke length of slider is a 90.27 mm and maximum velocity during the forward stoke that is cutting stoke is 358.25 mm/ sec and during the return stoke the maximum velocity of slider is 756.30 mm /sec

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VIII. RESULT

Motion study of Crank and slotted quick return mechanism is done in solidworks 2019.the graph is plotted as result of simulation for each link

A. Slider

1. Graph between Displacement and time

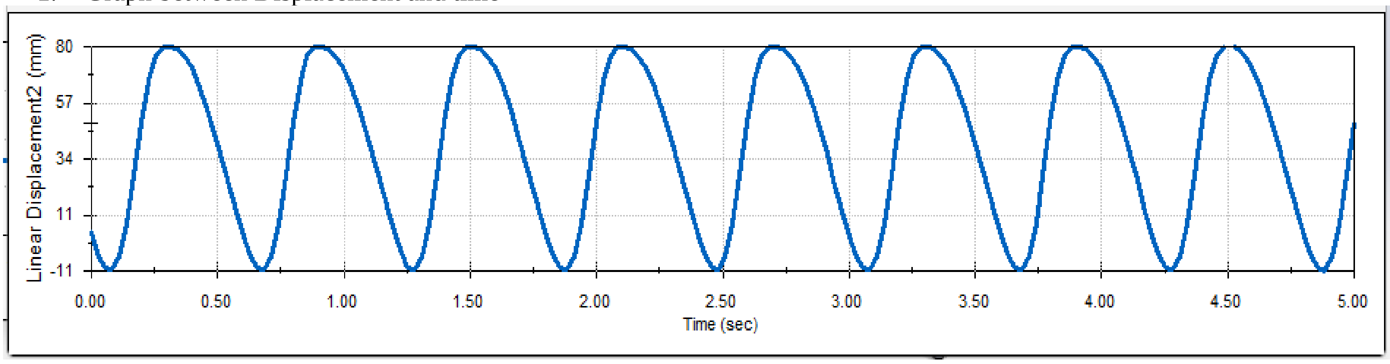

Fig. Graph between Displacement and time

The graph represents the displacement of slider of crank and slotted quick return mechanism over a time.it show how the position of the slider changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates displacement.as the crank rotates, it causes the slider to move back and forth, this movement is reflected in the displacement value of the graph. During the forward stroke, the displacement increases as the crank rotate and slider moves in one direction. Once the crank reaches its maximum rotation, the displacement decreases rapidly as the slotted link moves back to original position slider comes to its original position in 0.5 sec. It clearly seen that maximum displacement of the mechanism is 80mm.

2. Graph between Velocity and time

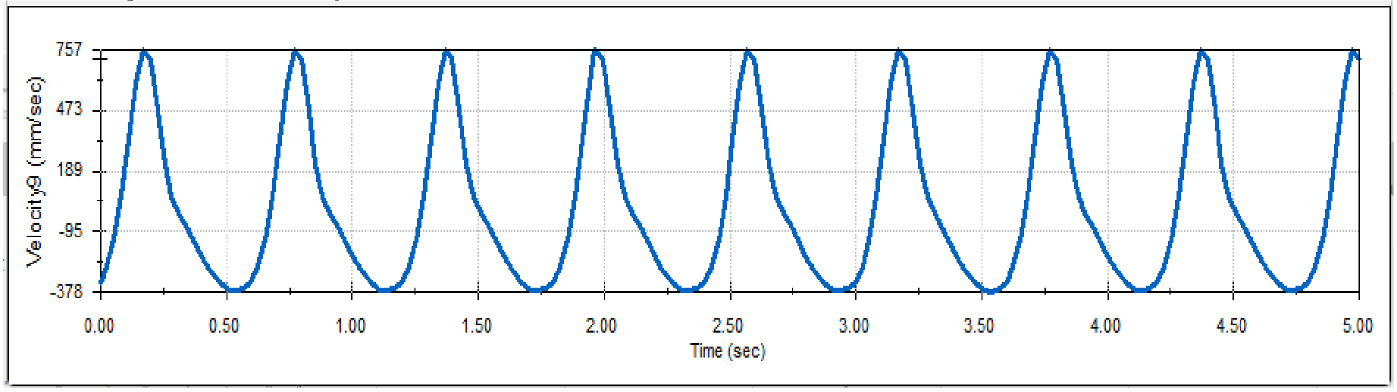

Fig. Graph between Velocity and time

The graph represents the velocity of slider of crank and slotted quick return mechanism over a time.it show how the velocity of the slider changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates velocity. During the forward stroke the velocity of slider increases as the mechanism enter in quick return stoke velocity of the slider decreases rapidly. The maximum velocity during the forword stoke is 356 and during the return stroke it is 757 mm/sec

3. Graph between acceleration and time

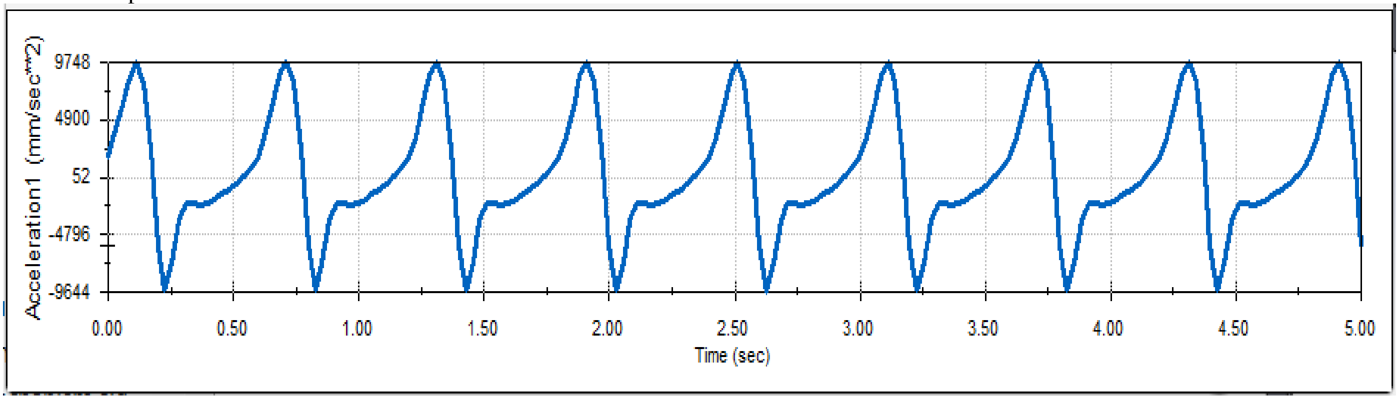

Fig. Graph between acceleration and time

The graph represents the acceleration of slider of crank and slotted quick return mechanism over a time.it show how the acceleration of the slider changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates acceleration. During the forward stroke, the acceleration graph shows the positive values, indicating the that the mechanism is accelerating in one direction. Once the mechanism enters in the quick return stroke, the acceleration graph displays negative value, indicating the deceleration as the mechanism changes the direction

B. Connecting rod

1. Graph between Displacement and time

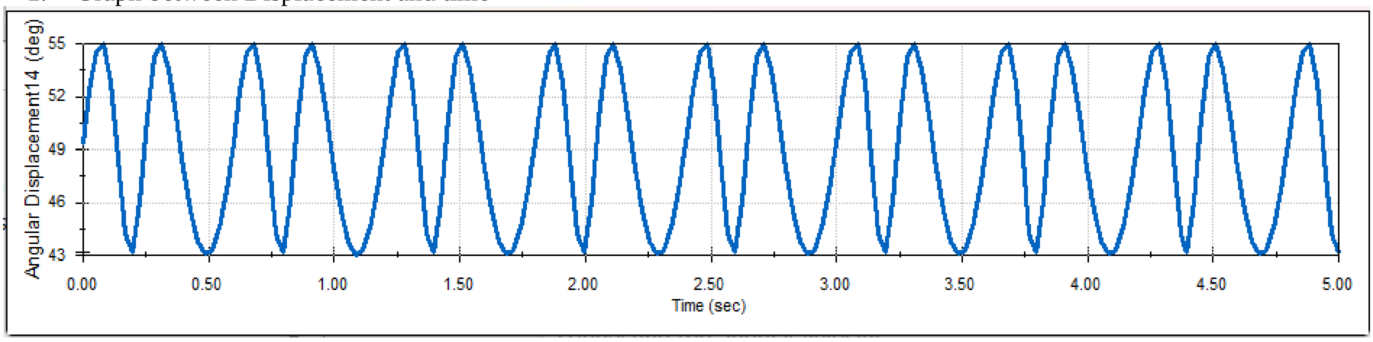

Fig. Graph between Displacement and time

The graph represents the displacement of connecting rod of the crank and slotted quick return mechanism over a time.it show how the position of the connecting rod changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates displacement. During the forward stroke, the angular displacement vs time graph shows an decreasing the value as the connecting rod extend away from the crank. Once the mechanism enters in this quick return stoke, the graph shows the increasing value of angular displacement as the connecting rod reaches to the original position.

2. Graph between Velocity and time

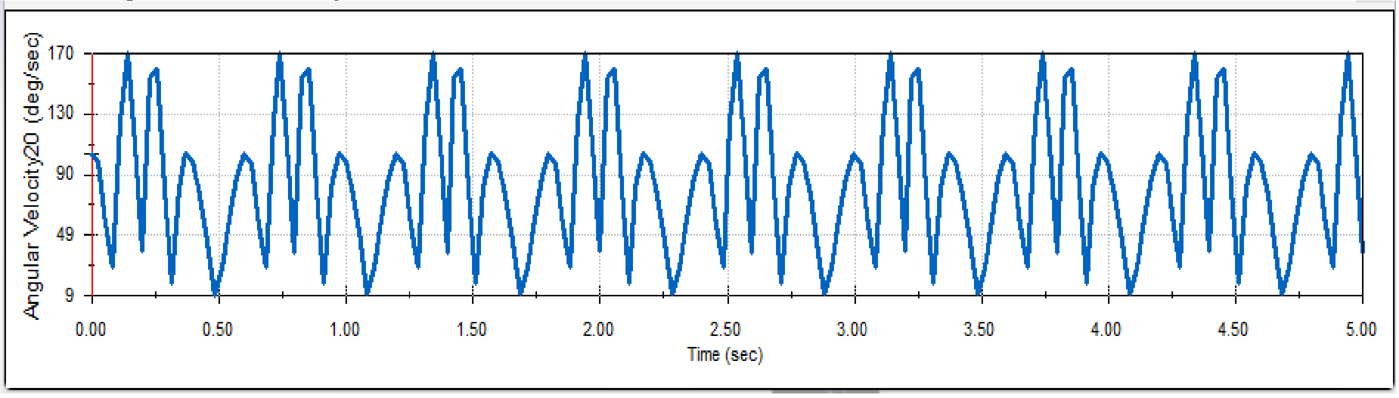

Fig. Graph between Velocity and time

The graph represents the velocity of connecting rod of the crank and slotted quick return mechanism over a time.it show how the velocity of the connecting rod changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates angular velocity. As shown in the graph at the start of the forward stroke angular velocity of the crank is near about 0 as the forward stoke start angular velocity rapidly increase first the decreases this happened twice in the forwardstoke. Same thing happened in also return stroke but rate of change of velocity less and also its maximum value also less.

3. Graph between acceleration and time

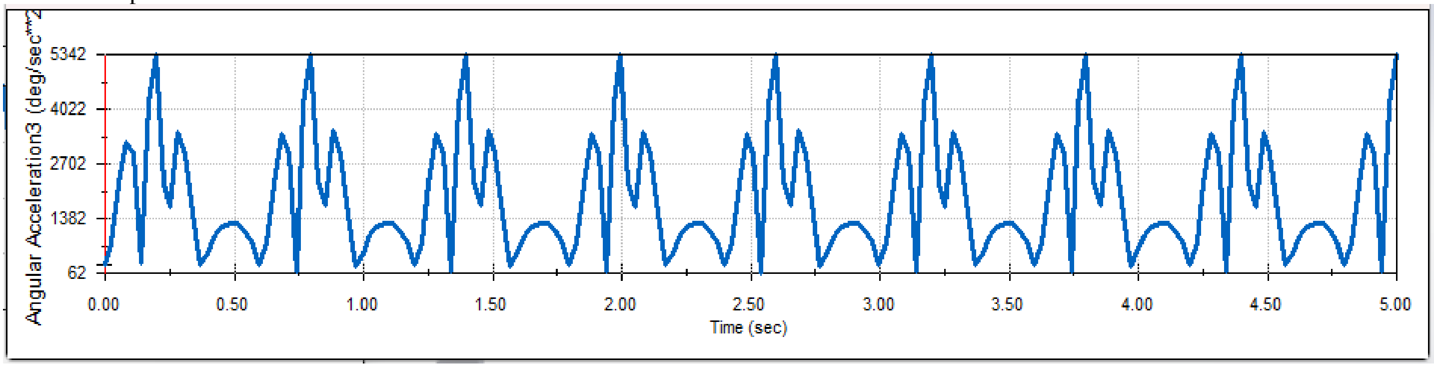

Fig. Graph between acceleration and time

The graph represents the acceleration of connecting rod of the crank and slotted quick return mechanism over a time.it show how the acceleration of the connecting rod changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates angular acceleration.As shown in the graph during the forward stroke rate of change of acceleration is more than that of the return stroke,forward stoke start from 0.05 sec and of during starting rate of change of acceleration decrease and then after some interval it start increasing after reaching maximum value again it decreasesand at the end of forward stoke again it start increasing. As quick return stokes start from 0.30 sec rate change of acceleration decrease after some interval it start increasing but rate of change of acceleration is less than that of the forward stoke.

C. Slotted link

1. Graph between Displacement and time

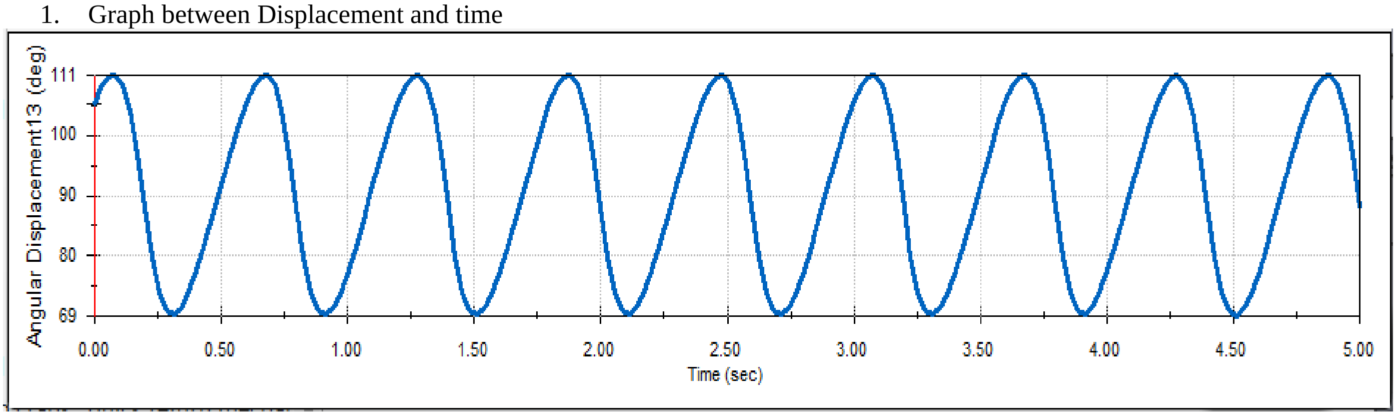

Fig. Graph between Displacement and time

The graph represents the displacement of slotted link of the crank and slotted quick return mechanism over a time.it show how the position of the slotted link changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates displacement. During the forward stroke, the displacement decreasing as the crank rotate and slider moves in one direction. Once the crank reaches its maximum rotation, the displacement increasing rapidly as the slotted link moves back to original position slider comes to its original position in 0.65 sec

2. Graph between Velocity and time

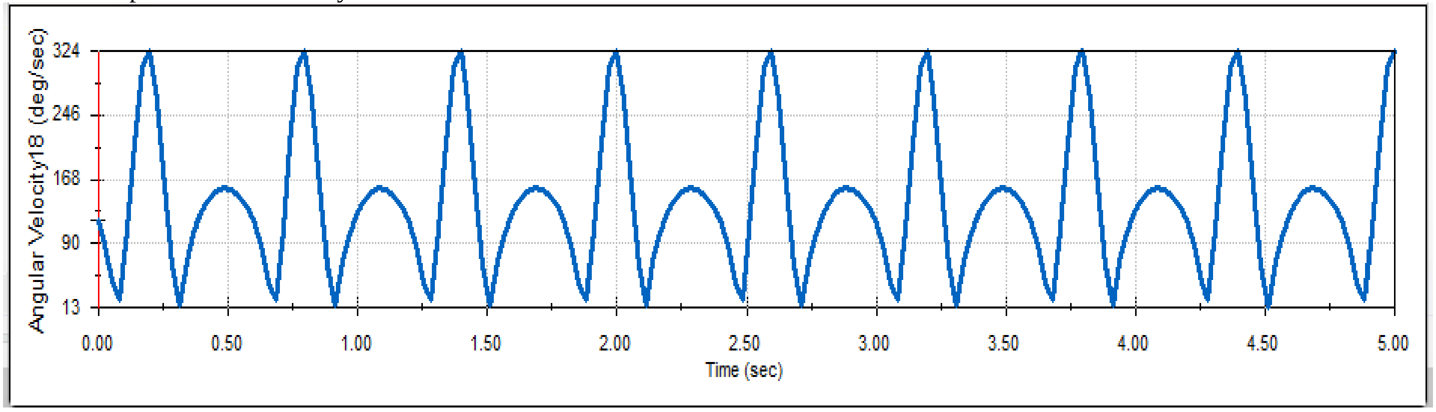

Fig. Graph between Velocity and time

The graph represents the velocity of slotted link of the crank and slotted quick return mechanism over a time.it show how the velocity of the slider changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates Angular velocity. During the forward stoke velocity changes rapidly as compare to return stroke. Slotted link achieves its maximum velocity during the forward stroke

3. Graph between acceleration and time

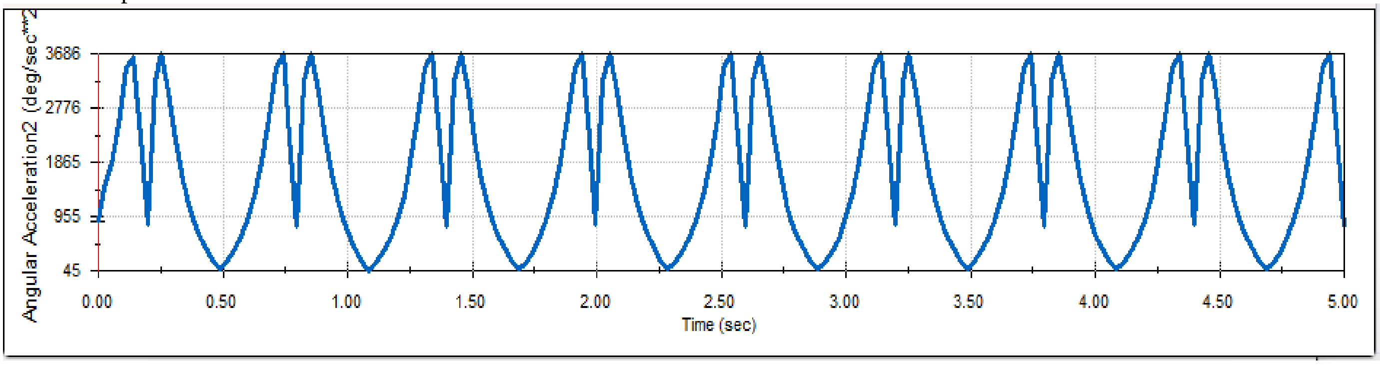

Fig. Graph between acceleration and time

The graph represents the acceleration of the crank and slotted quick return mechanism over a time.it show how the acceleration of the slider changes as time progress On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates Angular acceleration. From this we can conclude that rate of change of acceleration is more that of the return stoke.We also observe that rate of change of acceleration is 0 at the mid of the both stroke

D. Crank

1. Graph between Displacement and time

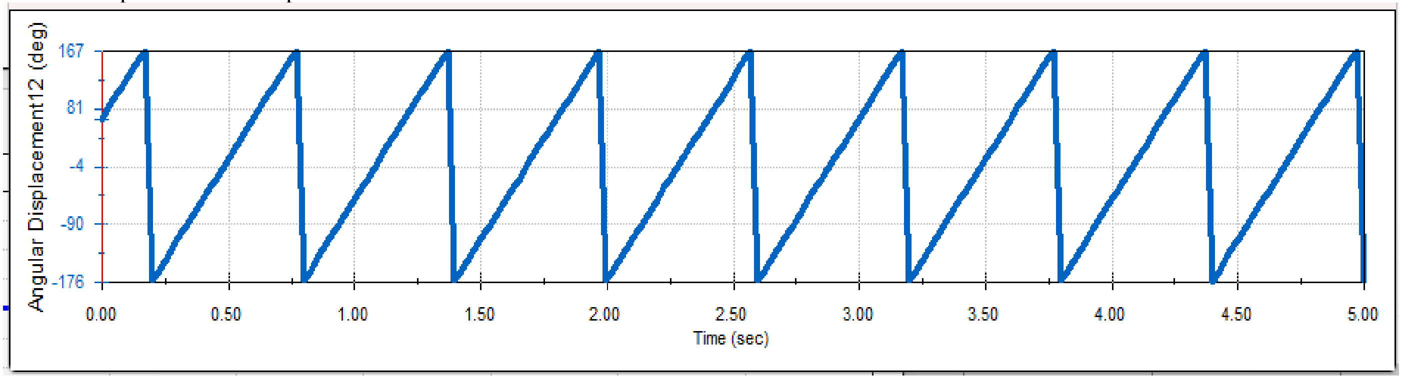

Fig. Graph between Displacement and time

The graph represents the displacement of the crank and slotted quick return mechanism over a time.it shows how the position of the crank changes as time progress; the On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates displacement. Graph between angular displacement and time shows the fixed pattern during the entire working cycle.

2. Graph between Velocity and time

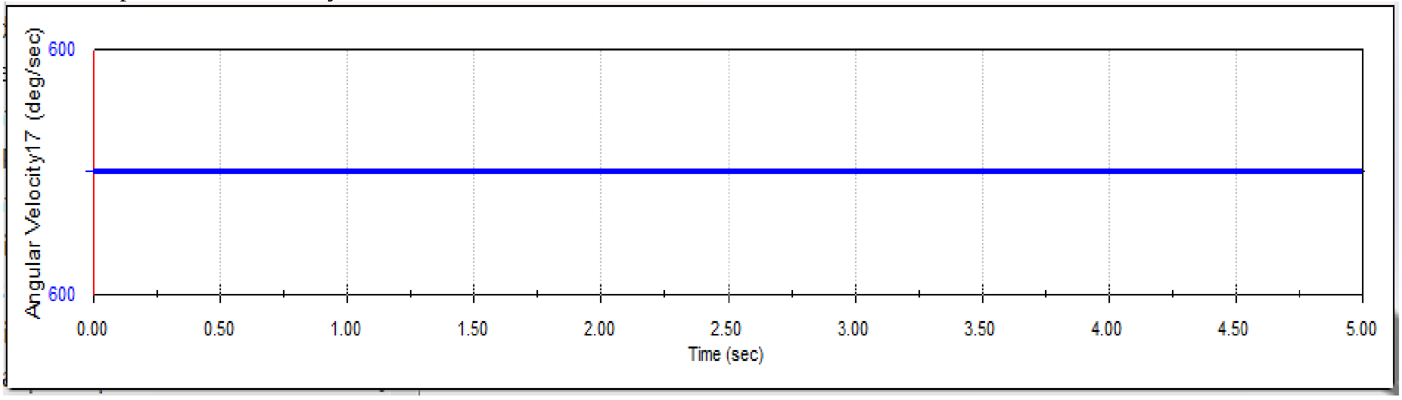

Fig. Graph between Velocity and time

The graph illustrates the angular velocity of the crank in the crank and slotted quick return mechanism plotted against time.it show how the angular velocity of the slider changes as time progress On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates displacement. During theworking crank is rotate at fix speed of 100 rpm that is 600 degree per second so that it does not show any variation with time

3.Graph between acceleration and time

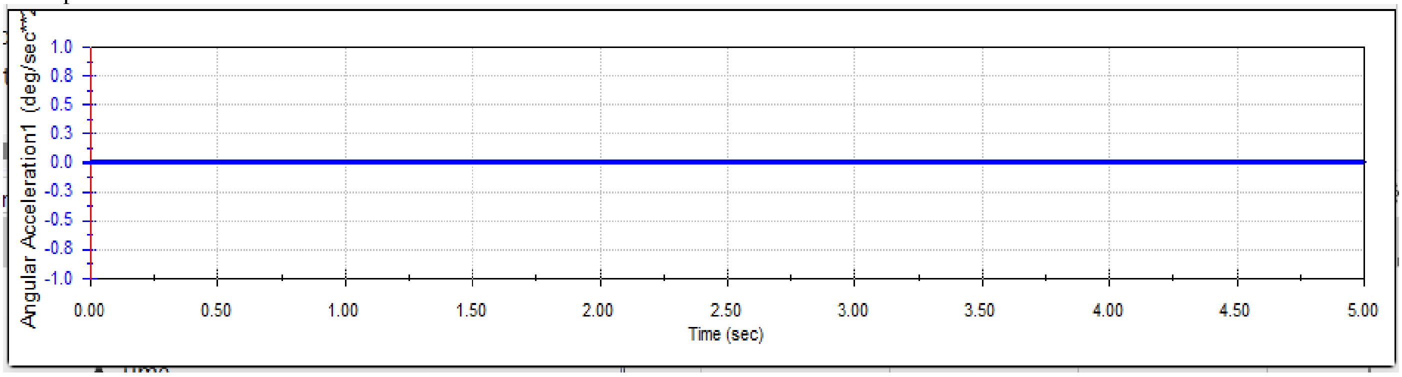

Fig. Graph between acceleration and time

The graph represents the acceleration of connecting rod of the crank and slotted quick return mechanism over a time.it show how the acceleration of the connecting rod changes as time progress, On the graph, the horizontal axis corresponds to time, whereas the vertical axis indicates angular acceleration. As the crank rotate at fixed speed of 100 rpm so velocity does not change with respect to time, We are aware that acceleration represents the rate at which velocity changes over time so that graph between the angular acceleration and time does not show the variation.

IX. CONCLUSION

In this mechanism, we have a crank connected to a rotating shaft, which drives a slider attached to a slotted link. As the crank rotates, it causes the slider to move back and forth along the slotted link. This mechanism is commonly used in machines where a quick return stroke is desired. Throughout the analysis, we examined the movement attributes of the mechanism, including the displacement, velocity, and acceleration of the slider.By simulating the mechanism in software like Solidworks, we can visualize and analyze its behavior in different operating conditions. We noted that the slider exhibits slow movement during the forward stroke and accelerates significantly during the return stroke, hence the term "quick return. By studying the kinematics and simulating the mechanism, we can optimize its design for better performance, reducing wear and tear, and improving overall efficiency.

X. ACKNOWLEDGMENT

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