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MODIFICATION OF SLIDER CRANK MECHANISM AND STUDY OF THE CURVES ASSOCIATED WITH IT

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ABSTRACT

The main objective of the modified slider-crank mechanism is to convert rotary motion into reciprocating motion and thus to obtain a "closed curved" motion at the reciprocating end instead of the linear to and fro motion. This is done by the modification of the slider-crank mechanism. The "closed curved" motion thus obtained can be used to generate useful work. A simple straight, a circular motion or/even an elliptical motion from a link of any mechanism is easily achievable. But our approach is to obtain a closed curved motion from a rigid link of the mechanism and to study the variations in the dimension and position of the rigid links and supports, variations in the shape and size of the closed curve along with the variations in the force, torque, angular velocity and angular acceleration associated with the links in the said modification of the slider crank mechanism. The above mentioned study of the changes in the obtained curve of the mechanism is done by using SAM - the Ultimate Mechanical Designer software and Solidworks-2012 software. One can easily modify the dimensions of the links of the mechanism to obtain the desired dimension of the curve thereby using it in useful work as need arises.

Keywords : Closed Curvature Motion, Slider-Crank Mechanism, SAM-The Ultimate Mechanical Designer Software, Solidworks-2012 Software, Rotary Motion, Reciprocating Motion, Force, Torque, Angular Velocity, Angular Acceleration.

I. INTRODUCTION

The Slider-crank mechanism is used to transform rotational motion into translational motion by means of a rotating crank shaft, a connecting rod and a sliding block. This paper is a study on the curves associated with certain modifications of the Slider-crank mechanism. The modifications include adding a pivot point to an extended connecting rod, so as to obtain a set of closed curves at the extended end for rotational motion of the crank, in addition to the orthodox translational motion of the sliding assembly.

II. DESIGN

2.1 The Modification

In the modification of the slider-crank mechanism [fig. 1], 1' is the cylinder of the sliding pair and 1 the pivoted crank end [fig. 2]. The piston of the sliding pair i.e. link 4, in case of the basic mechanism is removed in the modification; instead the link 3 or the connecting rod in case of the basic mechanism is extended and the connecting rod itself forms the sliding pair with the inside of the cylinder. The fixed cylinder of the basic mechanism or the cylinder end of the link1 [i.e. link 1' in case of the modification] is given a degree of freedom so that it can align itself parallel to the connecting rod [link 3] accordingly as the connecting rod moves from one alignment to the other due to the rotation of the crank [i.e. link 2]. But the mid portion of the cylinder [link 1'] is pivoted in such a way that it can oscillate about the pivoted point in the y-direction only and not in the x-direction and thus can guide the connecting rod by forming a sliding pair with it. The connecting rod may have a rigid or non-rigid part attached to it for better lubrication with the cylinder walls for forming the sliding pair, but we will not consider it as a separate link rather as a part of the link 3.

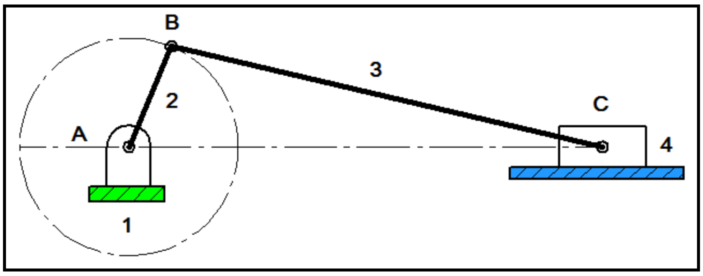

Fig 1: Slider Crank Mechanism

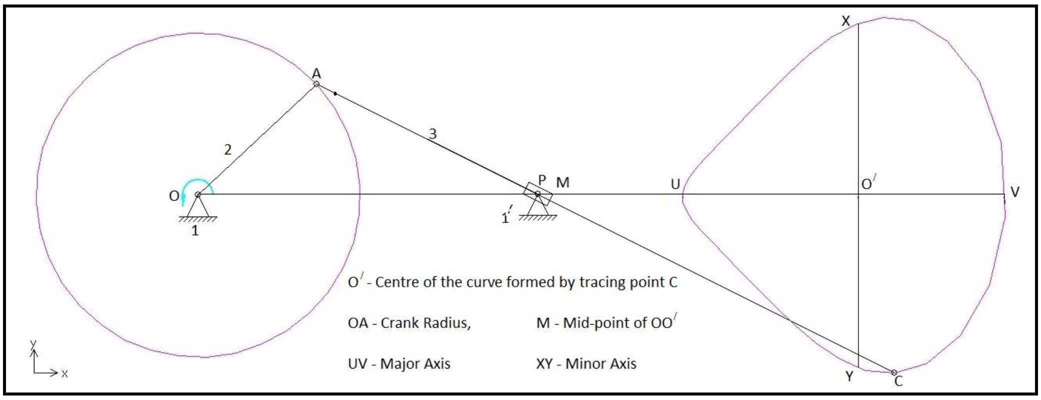

Fig 2: Modification of Slider Crank Mechanism

2.2 The Working

When the crank rotates, the connecting rod slides inside the lubricating cylinder [link 1'] and the end-point of the connecting link will trace a locus, which is a closed curve. The direction of the tracing of the curve will be opposite to that of the direction of motion of the crank. That is, if the crank rotates in the clockwise direction, then the end of the connecting rod will trace the closed curve on the counter-clockwise direction. The length of the major axis [refer fig. 2] of the closed curve will be equal to the diameter of the crank rotation i.e. twice the length of the crank. The length of the minor axis, will depend on the position of the pivot of the lubricating cylinder and on the length of the connecting rod. The lubricating cylinder will oscillate about the pivot in the plane of rotation of the crank thereby guiding the connecting rod to form the closed curve.

2.3 Kinematic Overview of the Design

The joints used in the modified slider crank mechanism are described below:

Table 1: Description of Joints

Fixed joint	Revolute joint	Prismatic joint
1	3	1

Table 2: Description of Motion, Moment and DOF

Description of degree of freedom and motion of the links for imposed motion is given below:

Moving Part	Revolute joint	Moment	Degree of Freedom
3	3	2	1

Table 3: Description of Mass and Length of Links

Description of the masses associated with the links is given below (assumed):

Diameter of links (m)	Length of link 2 (m)	Length of link 3 (m)	Gravity (m/s^2)	Density of material of link (kg/m^3)	Mass of link 2 (kg)	Mass of link 3 (kg)
0.03	0.3	2	9.8	7874 (iron)	1.67	11.13

III. ANALYSIS

After analyzing the modified slider crank mechanism in SAM (Synthesis and Analysis of Mechanism) - the Ultimate Designer software and Solidworks-2012 software it is found that the shape and size of the obtained closed curve depends mainly on two factors viz. the length of the connecting rod and the position of the pivot point which are discussed below. During analysis the naming of each links and nodes will be different. As the crank will be named is (1) with nodes at 1 and 2 and the connecting rod will be named as (3) with nodes at 2 and 4. The crank is fixed at point 1 and connecting rod is oscillating at point 3 which being the lubricating cylinder.

3.1 Change in Dimension of Connecting Rod

The size and shape of the closed curve depends on the length of the connecting rod. In this case, the pivot point of the lubricating cylinder is assumed to coincide with the midpoint of the line joining the center of the crank rotation circle (O) and the center of the closed curve (O'). It is seen that the curve approaches the shape of a circle with the increase of the length of the connecting rod. A curve of an exceptional shape is seen when the length of the connecting rod approaches the minimum possible length of the connecting rod which is nearly equal to the length of the diameter of the crank rotation circle i.e. twice the length of the crank. At the minimum possible length of the connecting rod, the curve traced resembles the shape of an arrow head. The curves formed are given below in the decreasing order of the length of the connecting rod [fig 2].

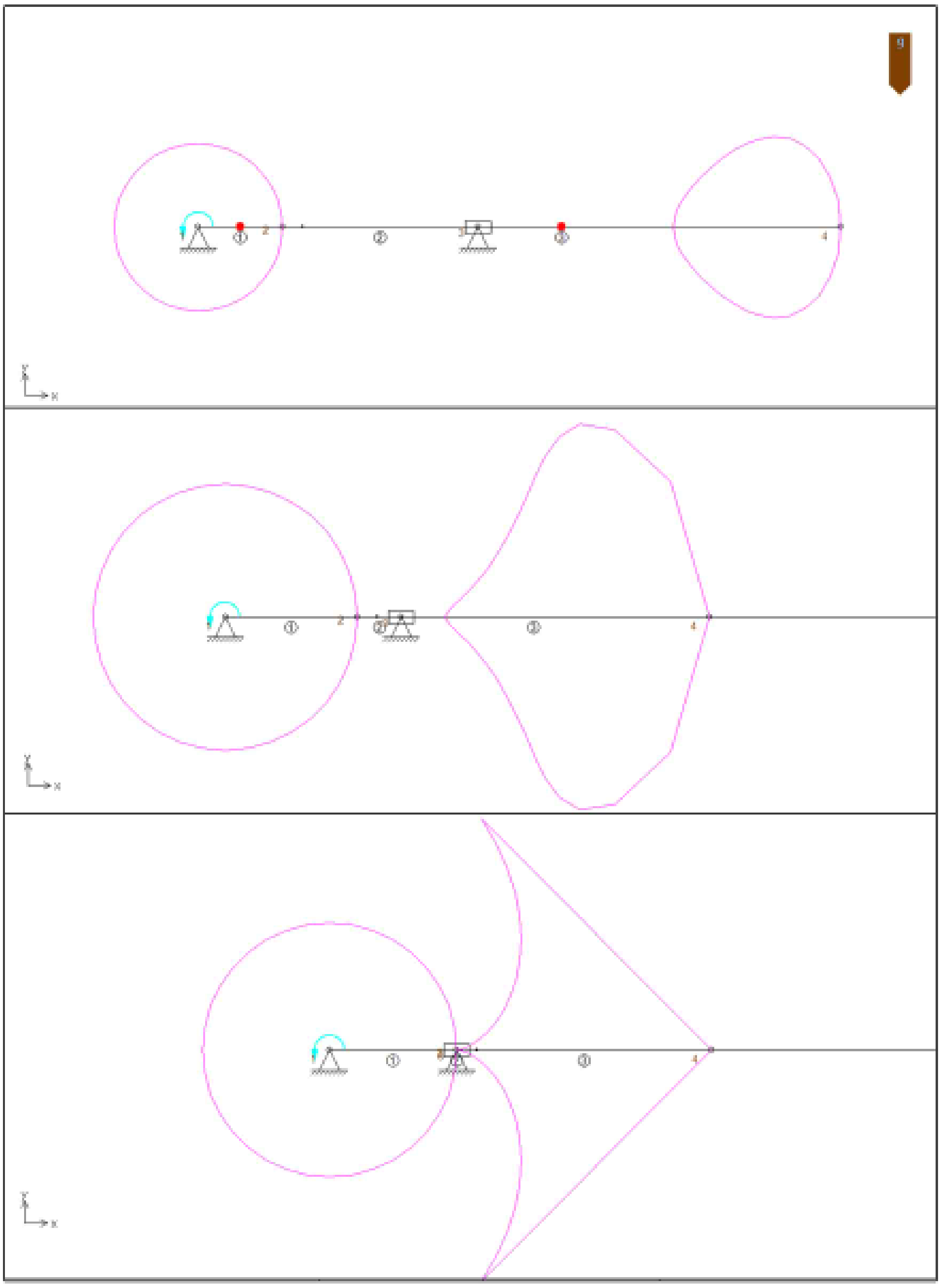

Fig 3: Change in Shape of the Closed Curve with Decreasing Size of Connecting Rod

3.2 Change in Position of the Pivot Point

The variations of the size and shape of the closed curve with respect to the change in the position of the pivot point of the lubricating cylinder can be described as follows:

3.2.1 Case I

When the pivot (P) coincides with the midpoint (M) of the line joining the center of the crank rotation circle (O) and the center of the closed curve (O') [line OO' in fig. 2].

In this case, the length of the minor axis will be almost equal to the crank radius and the curve formed will be almost like the shape of an egg [refer fig. 4].

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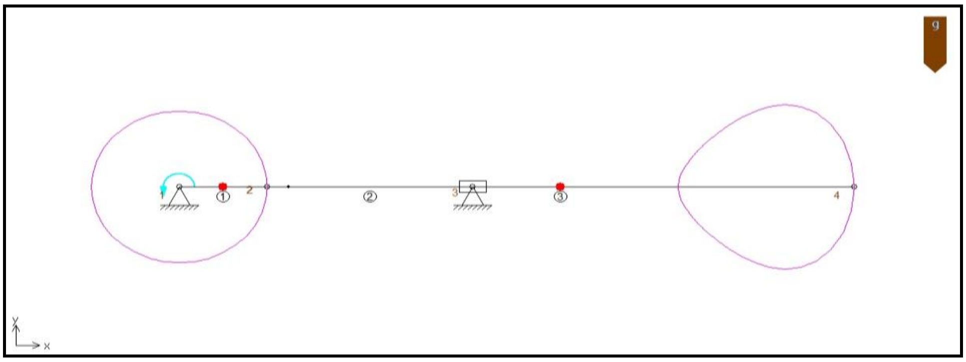

Fig 4: Lubricating Cylinder (pivot point) at the Midpoint of Line Joining the Centre of the Crank Rotation Circle and the Centre of the Closed Curve

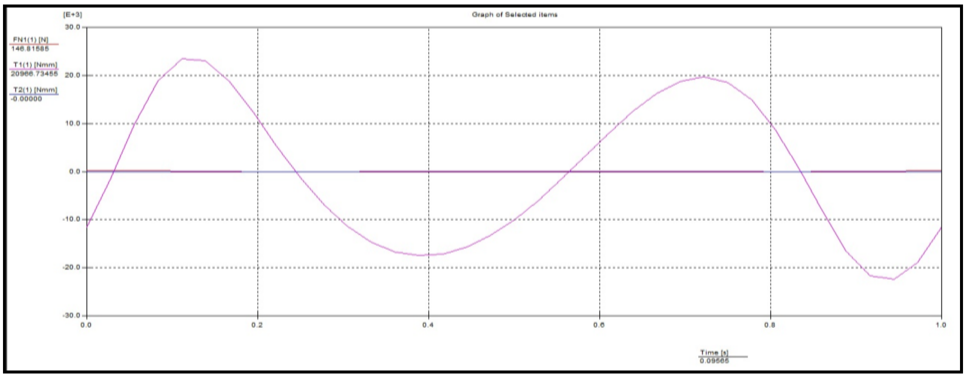

Fig 5: Force & Torque Analysis of Crank w.r.t. Time

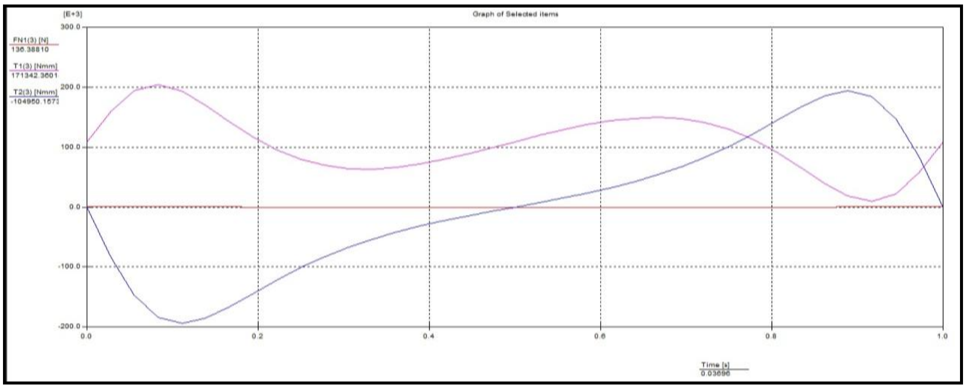

Fig 6: Force & Torque Analysis of Connecting Rod w.r.t. Time

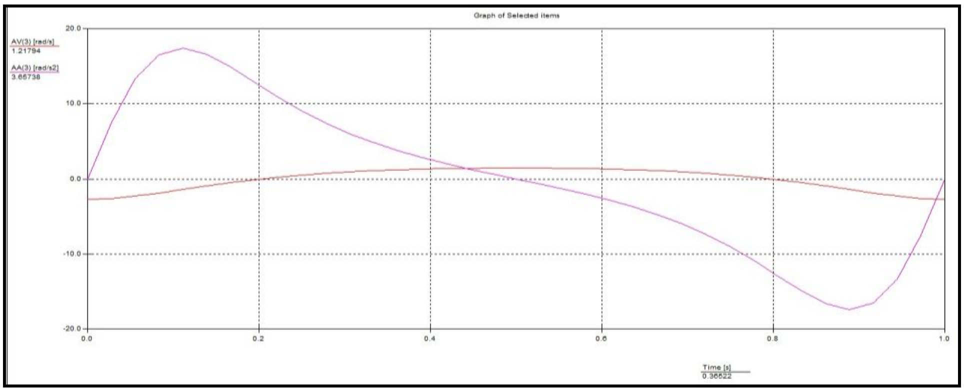

Fig 7: Angular Velocity & Angular Acceleration of Connecting Rod w.r.t. Time

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3.2.2 Case II

When the pivot (P) is towards the right of the mid-point (M) of the line joining the center of the crank rotation circle, and the center of the closed curve.

In this case, minor axis will be shorter in length than obtained in the first case [refer fig. 8].

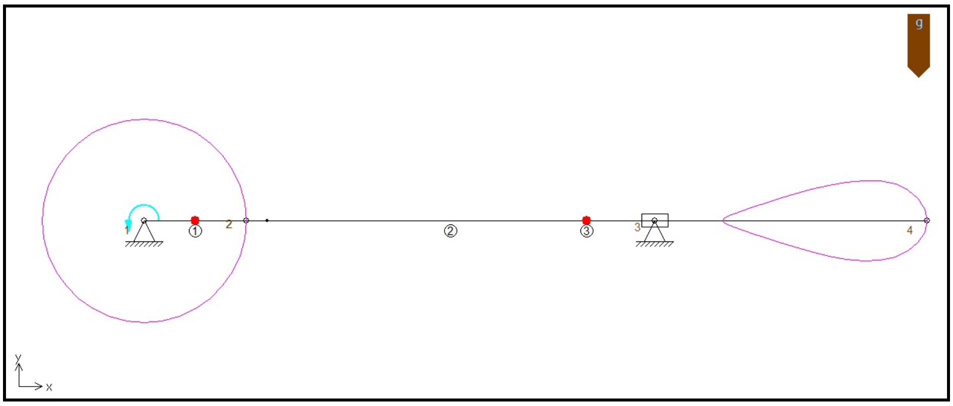

Fig 8: Lubricating Cylinder at Right to the Midpoint of Line Joining the Centre of the Crank Rotation Circle and the Centre of the Closed Curve

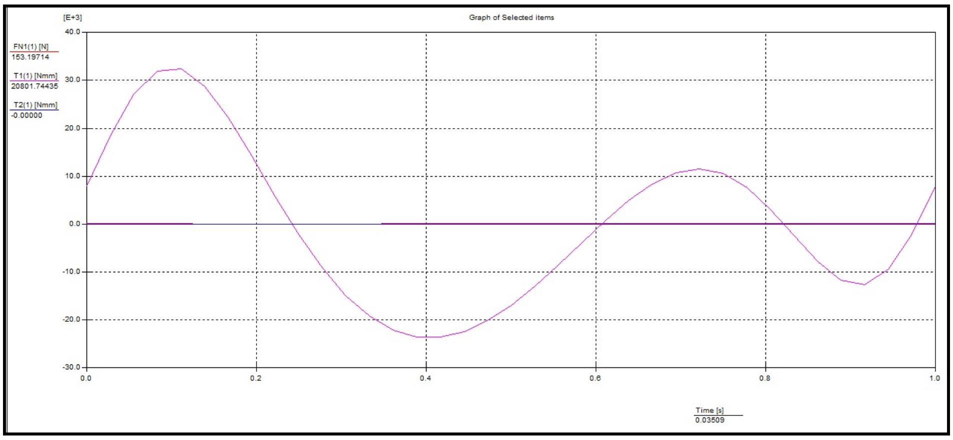

Fig 9: Force & Torque Analysis of Crank w.r.t. Time

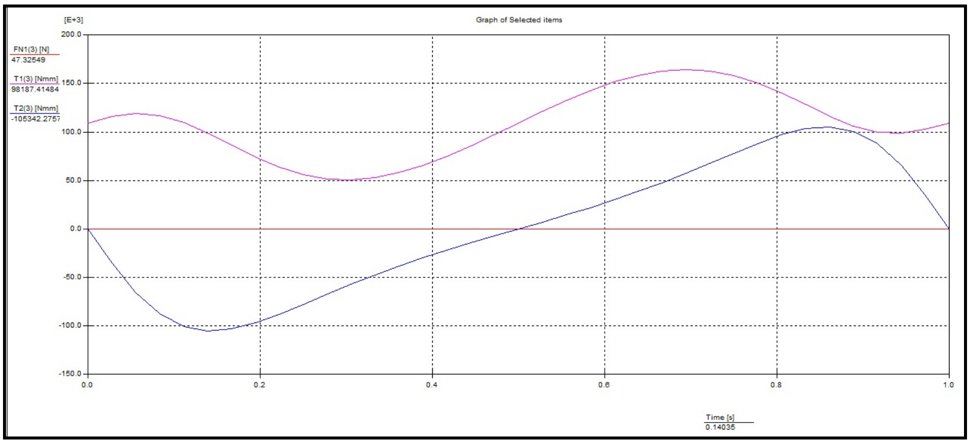

Fig 10: Force & Torque Analysis of Connecting Rod w.r.t. Time

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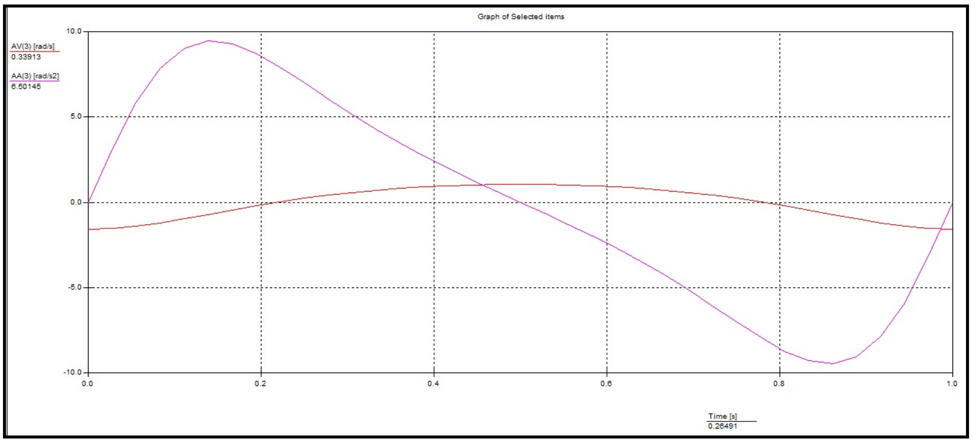

Fig 11: Angular Velocity & Angular Acceleration of Connecting Rod w.r.t. Time

3.2.3 Case III

When the pivot (P) is towards the left of the mid-point (M) of the line joining the center of the crank rotation circle and the center of the closed curve. Here again two cases arise as described below:

3.2.3.1 Case III(a)

When the pivot (P) is just to the left of the mid-point (M) of the line joining the center of the crank rotation circle and the center of the closed curve.

In this case, a curve of the shape of an umbrella or an arrow is formed [refer fig. 12].

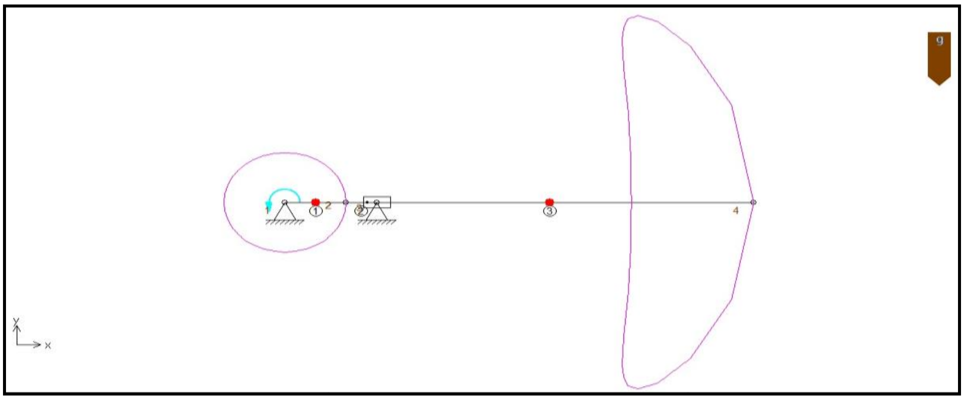

Fig 12: Lubricating Cylinder at Left to the Midpoint of Line Joining the Centre of the Crank Rotation Circle and the Centre of the Closed Curve

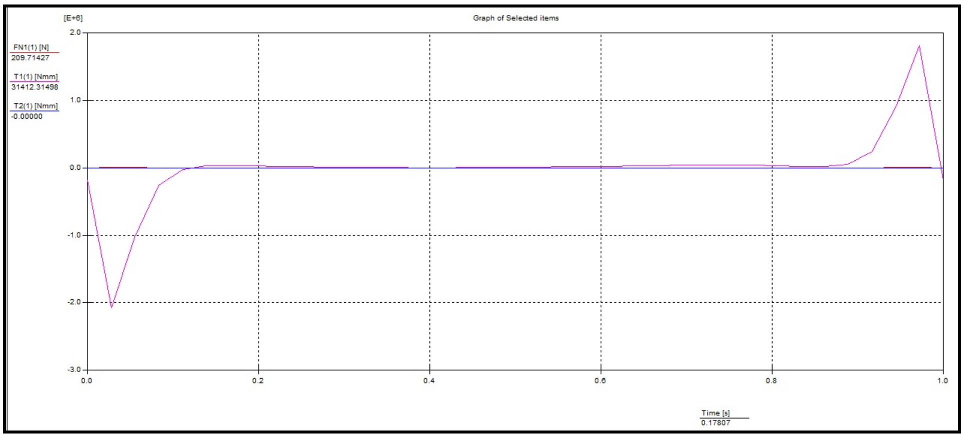

Fig 13: Force & Torque Analysis of Crank w.r.t. Time

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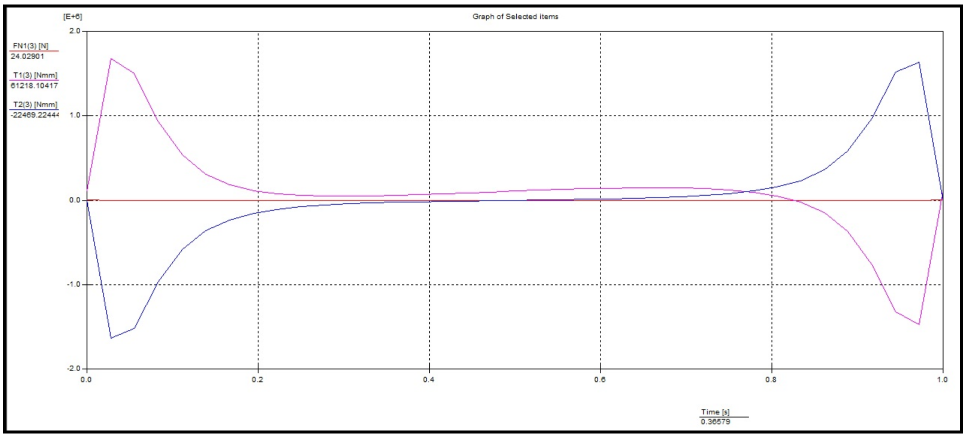

Fig 14: Force & Torque Analysis of Connecting Rod w.r.t. Time

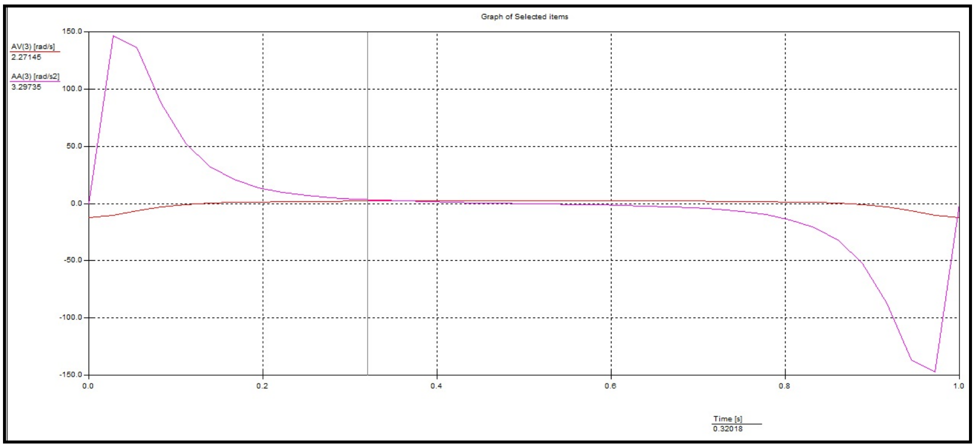

Fig 15: Angular Velocity & Angular Acceleration of Connecting Rod w.r.t. Time

3.2.3.2 Case III(b)

When the pivot (P) is towards extreme left of the mid-point (M) of the line joining the center of the crank rotation circle and the center of the closed curve or just near the crank rotation circle.

In this case, an exceptional curve is formed. The curve formed has two loops towards the crank side of it [refer fig. 16].

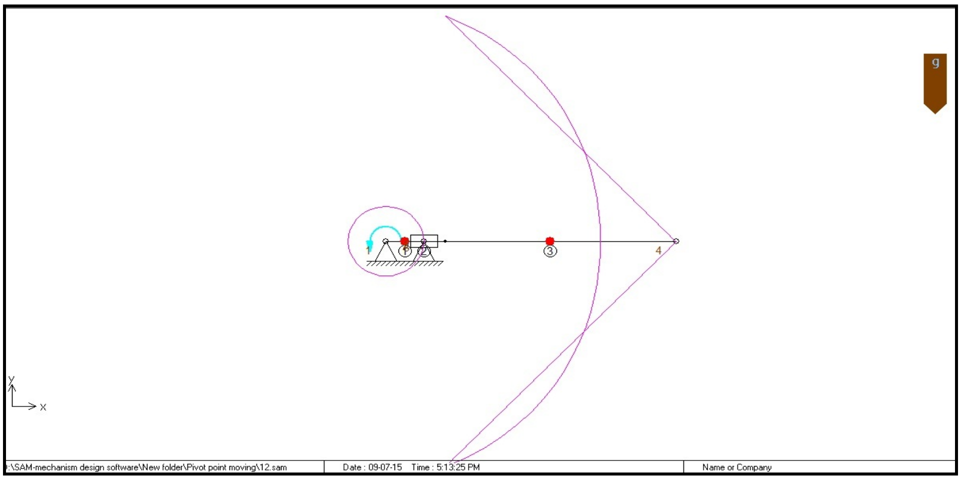

Fig 16: Lubricating Cylinder at Extreme Left (Near Node 2) to the Midpoint of Line Joining the Centre of the Crank Rotation Circle and the Centre of the Closed Curve

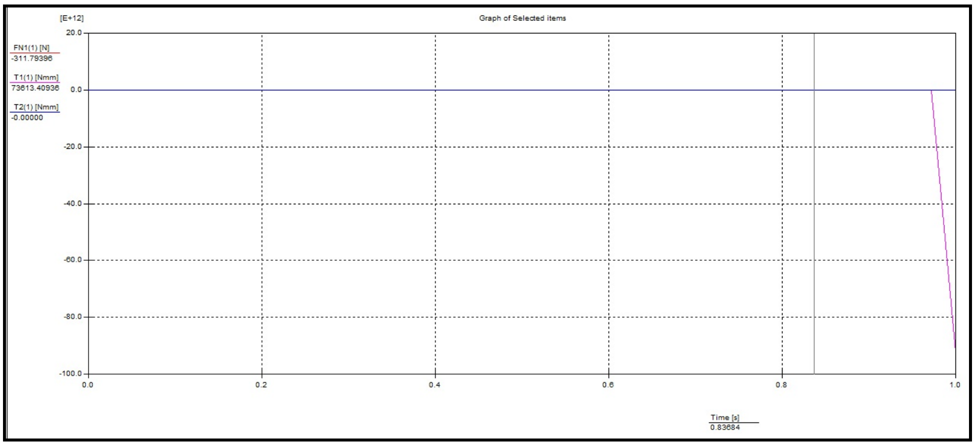

Fig 17: Force & Torque Analysis of Crank w.r.t. Time

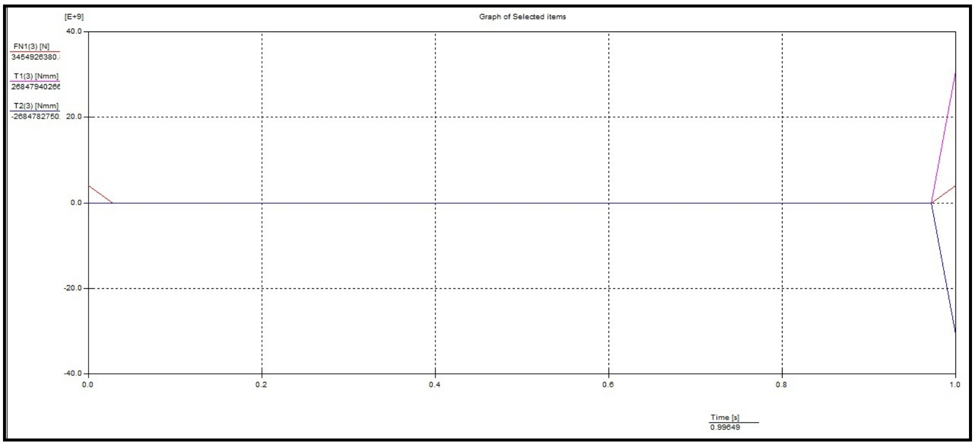

Fig 18: Force & Torque Analysis of Connecting Rod w.r.t. Time

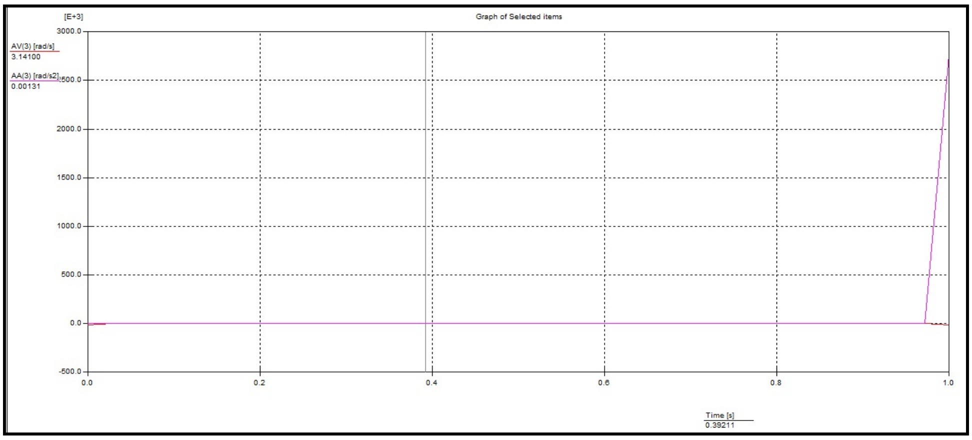

Fig 19: Angular Velocity & Angular Acceleration of Connecting Rod w.r.t. Time

3.2.4 Case IV

When the pivot point (P) or the lubricating cylinder co-incides with the node 2 then the movement of the entire mechanism cease.

IV. NOMENCLATURE

FN1(1), FN1(3)	:	Normal force acting at the mid-point of crank and connecting rod respectively.
T1(1), T2(1)	:	Torque acting on crank with respect to node1 and node2 respectively.
T1(3), T2(3)	:	Torque acting on connecting rod with respect to node2 and node4 respectively.
AV(3), AA(3)	:	Angular velocity and Angular acceleration of the connecting rod.

V. CONCLUSION

All the above three cases can be used to obtain useful work but in comparison, the case I and case II will be more useful.

In the process of crank rotation, the mechanism or the end point of the connecting rod will exhibit higher velocity for the part on right i.e. the outer part of the closed curve in comparison to the left part during the formation of the closed curve.

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