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MOTION ANALYSIS OF POINT OF A SIMPLE MECHANISM

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Abstract: This article deals with motion analysis of point of a simple mechanism executing a rotational movement. We analysed the movement of its end points. The trajectories of points is cardioids. Numerical solution was implemented by classical kinematics using different coordinate systems, while model mechanism has been also modelled and solved in the program MSC ADAMS View.

1 Introduction

In addressing the motion of machine parts, machines and equipment it is necessary to first create a kinematic model. Kinematic model of a device schematically captures all its properties which are essential in kinematic analysis i.e. individual members with dimensions, kinematic pairs, and so on [1-5].

Conventional numerical solution uses vector calculus as the basic mathematical apparatus because the main kinematic variables are vector quantities.

For analytical kinematic analysis of movement different coordinate systems may be used. According to the kind of movement we can choose the appropriate coordinate system for that model configuration thus simplifying the solution [3-8].

Classical numerical solution of movement kinematics is often lengthy and difficult especially for complex kinematic models with different movements. To simplify and expedite solutions a graphical solution may be used which is nowadays replaced with a solution using computer techniques using various software products. These software products ease the investigator's effort. Investigator enters the model configuration and the input data and the program calculates the required outputs. These data can be presented in a tabular form or program draws graphical results. One of the software products suitable for kinematic analysis is MSC ADAMS View program that allows to model kinematic chains and solve their motion [9-13].

2 Cardioid motion

Conchoidal movement is if the line p of the moving body passes through the point of the base frame C (the central point - the pole of movement) and the body point Q describes the control curve q (Figure 1).

The trajectories of body points are called conchoids. Conchoidal motion is a special case of point-to-curve motion. If the central point lies on the control circle, this is a special case where point C is still the vertex of the right angle of the triangle above the diameter QP. The stationary polodia k_1 is a circle identical to the driving circle ($q = k_1$). The driving polodia is the circle with the double radius k_2. It is a cardioid movement.

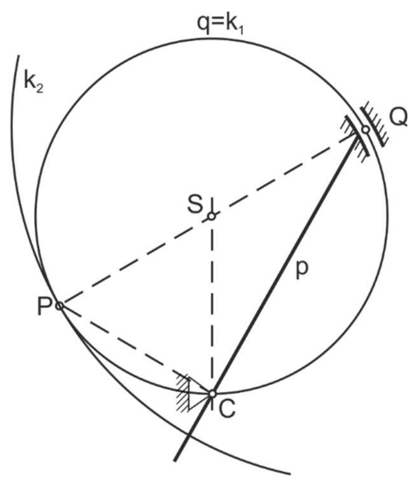

Figure 1 Point-to-curve motion

Cardiodic motion is said if each of the selected body lines passes a given point of the base frame. Each line connected to the body and passing through the point Q will slide over the point of the base frame C lying on the stationary polodia. Every movement of the body whose two lines slide along the base frame circle is cardioid.

Inversion of elliptical motion is obtained by:

a) moving the sides of an angle of constant size through two fixed points,
b) rolling a circle on another of half the size fixed inside it,
c) as a result of (a) and (b), making a point Q on a line CQ trace a circle, whilst so constraining this line that it continues to pass through a fixed point C on the circle.

The pole is invariably diametrically opposite the moving point O on the fixed circle.

Such motion is called cardioid because the paths of points involved are heart-shaped or of a shape derived from this (Figure 2). The diagram shows a line C_1AC_2 having a point A which traces the fixed circle k_1, whilst the line itself invariably passes through the fixed point B on circle k_1 [14].

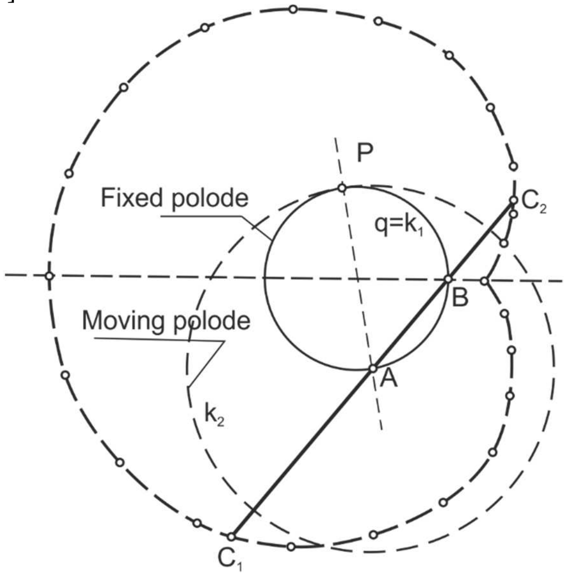

Figure 2 Cardioid motion

3 Point movement example

We analyse the movement of point C on the line p, Figure 3. The line p is moving in the plane $0, x, y$ so that it always goes through the point 0, the point A of the line p moves in a circle with a radius R. The angular velocity of the line p is $\omega = const. > 0$. In time $t_0 = 0$ is $p \equiv x$, $\overline{AC} = 2R$.

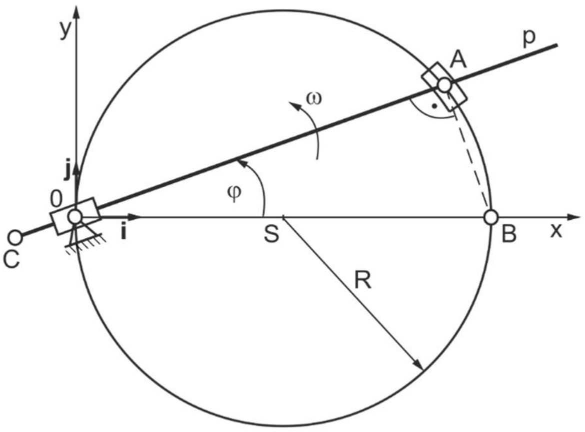

Figure 3 Mechanical system

Line p carries out a uniform rotational motion around the point 0 and in time $t_0 = 0$ is $p \equiv x$.

By introduction of the polar coordinate system we get $\rho = \rho(t), \varphi = \varphi(t)$.

Since $\omega = const.$, then $\varphi = \omega t$.

From triangle 0AB we get (1) $\rho = \overline{0A}$, and

$$\rho = 2R\cos\varphi = 2R\cos\omega t\,. \qquad (1)$$

Polar coordinates ρ, φ of the point A of line p in time t are given by following (2):

$$\varphi = \omega t,\;\; \rho = 2R\cos\omega t \qquad (2)$$

Position vector (3) r of the point A of line p in time t using Cartesian coordinate system is given by:

$$\mathrm{r} = x\mathrm{i} + y\mathrm{j}, \qquad (3)$$

where x,y (4), (5) are coordinates of the point A of line p in time t are according to the picture:

$$x = \rho\cos\varphi = 2R\cos^2\omega t \qquad (4)$$
$$y = \rho\sin\varphi = 2R\cos\omega t\sin\omega t \qquad (5)$$

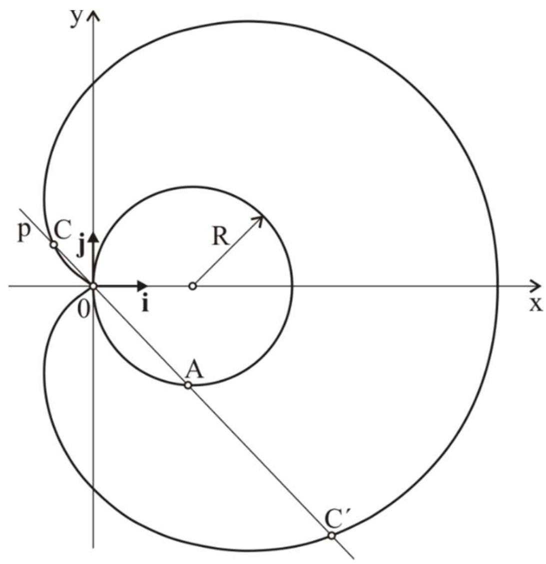

Figure 4 Trajectories of points A and C

Position vector (6) is

$$r = (2R\,cos^2\,\omega t)i + (2R\,cos\,\omega t\,sin\,\omega t)j. \qquad (6)$$

To be able to determine the trajectory of point C, we need to know the parametric equations of the trajectory given by the coordinates of C in relation to time t [15,16]

The coordinates of the point C can be determined (7), (8) from the image

$$x_C = -\overline{0C}\cos\varphi = -\overline{0C}\cos\omega t, \qquad (7)$$
$$y_C = -\overline{0C}\sin\varphi = -\overline{0C}\sin\omega t. \qquad (8)$$

The distance $\overline{0C} = \overline{AC} - \overline{0A}$, while (9), (10)

$$\overline{AC} = 2R, \qquad (9)$$
$$\overline{0A} = \rho = 2R\cos\omega t. \qquad (10)$$

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By modification we get the coordinates (11), (12) or parametric equations of the trajectory of the point C.

$$x_C = -2R(1-\cos\omega t)\cos\omega t, \qquad (11)$$
$$y_C = -2R(1-\cos\omega t)\sin\omega t. \qquad (12)$$

Eliminating the parameter t from the parametric equations we get the equation (13) of trajectory of point C

$$(x^2+y^2-2Rx)^2 = 4R^2(x^2+y^2). \qquad (13)$$

Resulting equation is the equation of a cardioid. The trajectory of the point C is thus a cardioid, Figure 4.

4 Simulation in MSC ADAMS View

MSC ADAMS View allows to model, analyse and optimize virtual prototypes of future products, investigate their properties before producing the real prototype and now covers over 50% of the world market in its area. It is also an appropriate tool for the development of miniature mechatronic elements as well as the examination of complex systems.

The given mechanism was modelled in MSC ADAMS View and the initial parameters were provided. In Figure 5 there is the model in motion with trajectories of points A and C.

In Figure 6 there is the position vector of the point C in time t and in Figure 7 is the position vector of the point A in time t, velocity and acceleration. Trajectory of the point C is in Figure 8 and Figure 9.

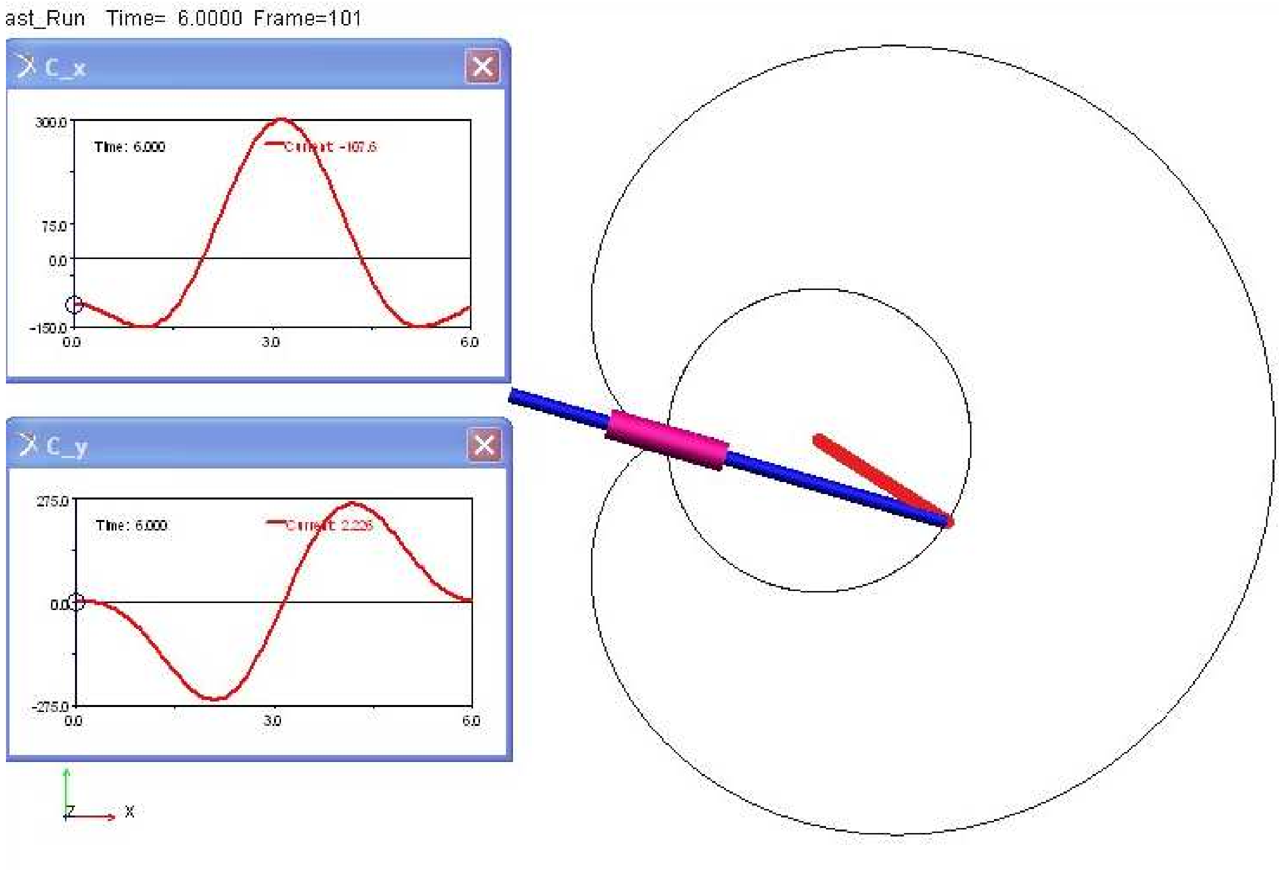

Figure 5 Position of the mechanism in the movement

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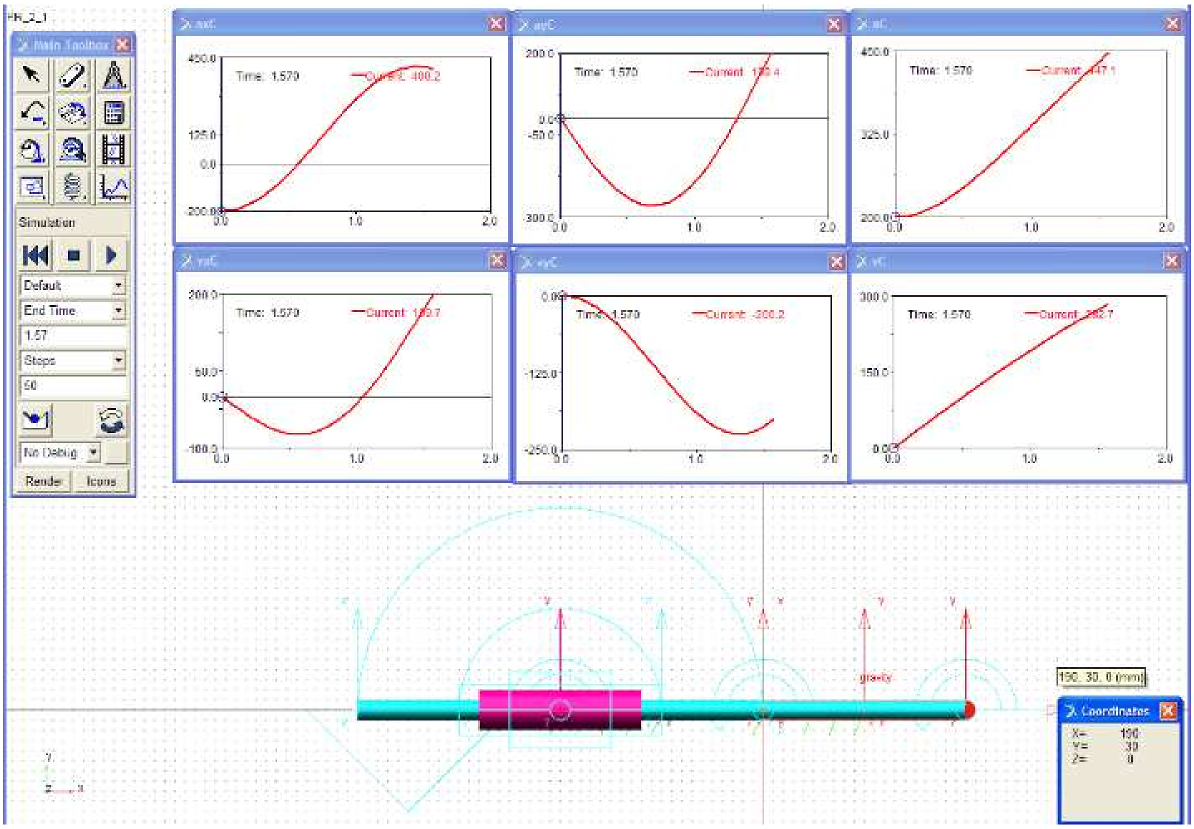

Figure 6 Speed and acceleration of the points C

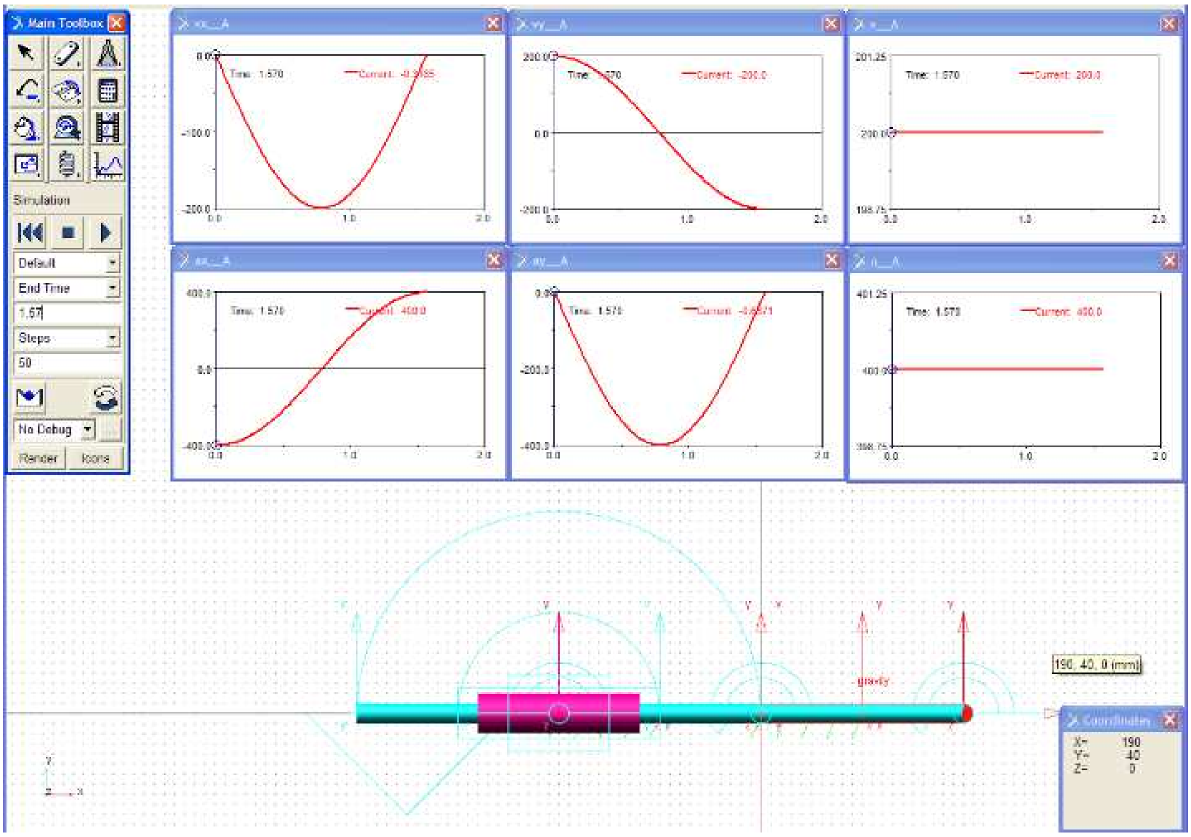

Figure 7 Speed and acceleration of the points A

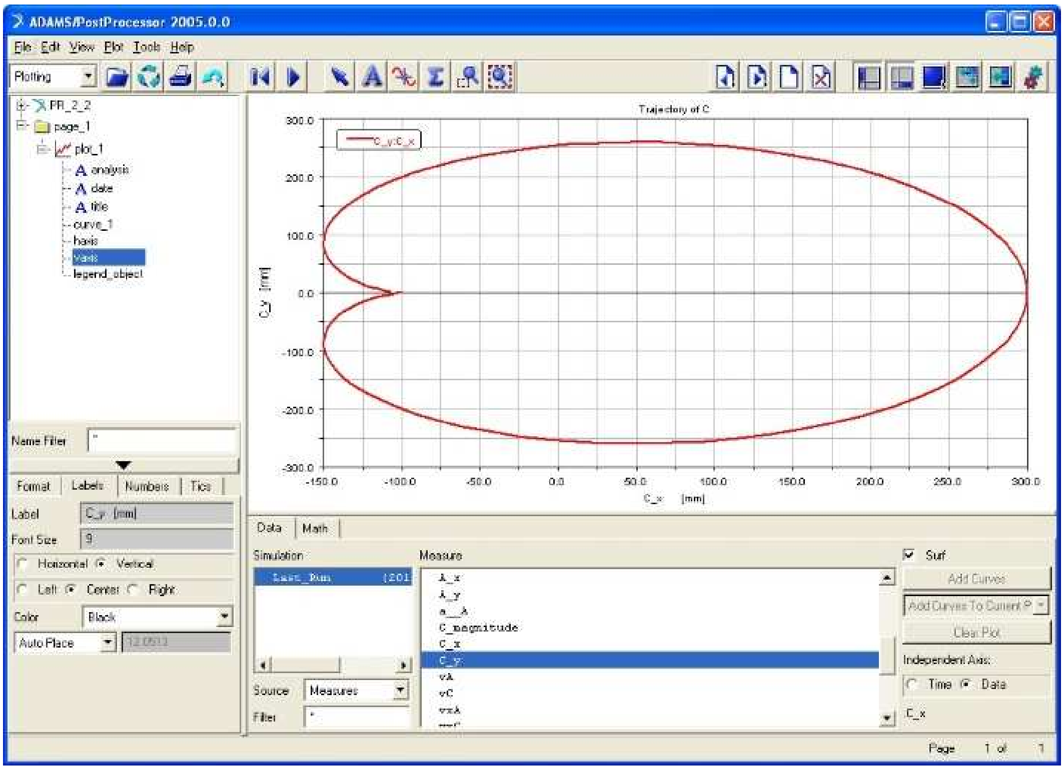

Figure 8 ADAMS PostProcessor

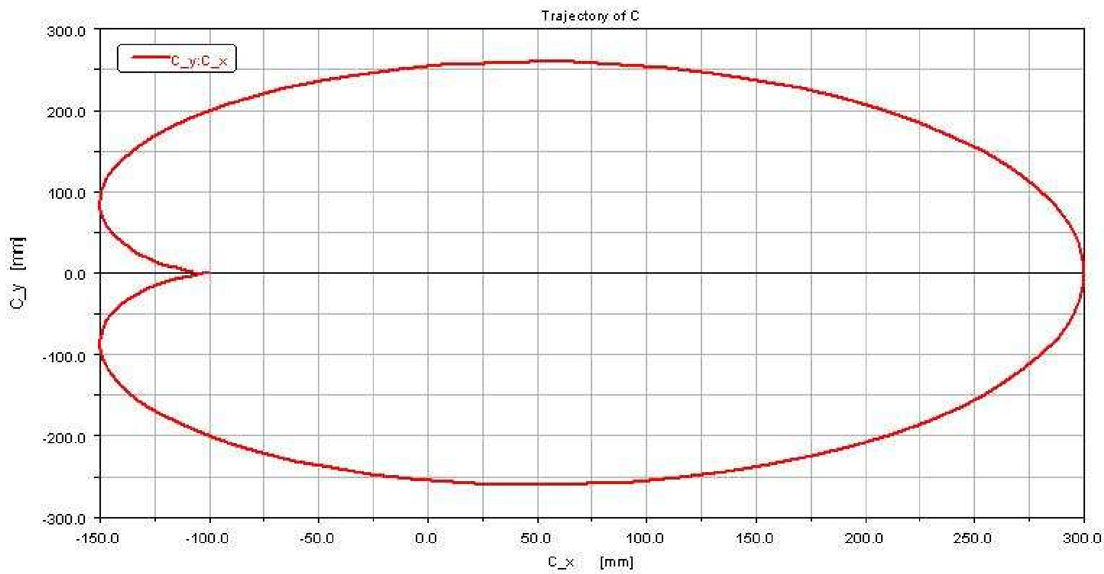

Figure 9 Trajectory of the point C in x-y plane

5 Conclusion

In the work is shown a procedure for solving kinematic problem of the mechanism using analytical solution and modelling in MSC Adams View. MSC Adams View allows to simulate moving of such mechanical systems. Results are obtained in form of time diagram of the desired variables. Tasks are solved numerically, model is compiled by using program MSC Adams View. Mastering this methodology provides a suitable tool for solving problems of teaching and practice.

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