

# The kinematic analysis of the third class mechanism

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**Abstract.** It is necessary to make link mechanisms calculation to the strength at designing of flat link mechanisms of high class after definition of block diagrams and link linear sizes i.e. it is rationally to choose their forms and to determine the section sizes. The algorithm of the definition of dimension of link mechanism lengths of high classes (MHC) and their metric parameters at successive approach is offered in this work.

**Keywords:** error, mechanism, generalized coordinates, point position, vector method.

## 1. Introduction

At the solution of synthesis problems of transfer mechanism with the difficult transfer function including stops of the output link, we often come to the third class link mechanism. This mechanism can be considered formally as a four-bar linkage with a variable length of the piston rod, then implementation of difficult laws of the movement is obviously reached. It is necessary to know point functions and transfer functions of all links for the further dynamic investigation of these mechanisms. The vector method of the kinematic analysis of the third class mechanism based on the principle published in the work, is offered. We represent link length of the mechanism in the form of vectors, as shown in Fig. 1. We make four independent vector equations of circuit completeness.

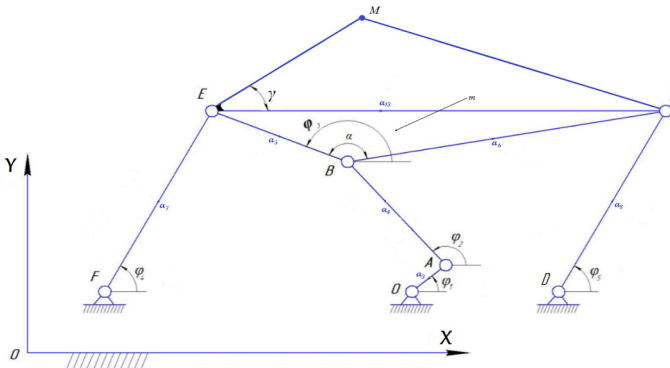


Fig. 1. The kinematic scheme of six-bar mechanism,  $\varphi_0$  – generalized coordinate;  $\varphi_{i(i=1,2,\dots,5)}$  – points of link mechanism which are defined by the method of the conditional generalized coordinates

It is necessary to find errors of piston rod point  $M$  of the studied third class mechanism occurring in metric parameters:  $a_1 = x_o$ ,  $a_2 = y_o$ ,  $a_3 = l_{OA}$ ,  $a_4 = l_{AB}$ ,  $a_5 = l_{BE}$ ,  $a_6 = l_{BD}$ ,  $a_7 = l_{EF}$ ,  $a_8 = l_{DG}$ ,  $a_9 = x_F$ ,  $a_{10} = y_F$ ,  $a_{11} = x_G$ ,  $a_{12} = y_G$ ,  $a_{13} = l_{ED}$ .

We write down coordinates of  $M$  point:

$$\begin{cases} x_M = a_9 + a_7 \cos \varphi_4 + EM \cos \gamma, \\ y_M = a_{10} + a_7 \sin \varphi_4 + EM \sin \gamma. \end{cases} \quad (1)$$

The errors of the  $M$  point position is defined by formulas:

$$\begin{cases} \Delta x_{Mj} = \frac{\partial x_{Mj}}{\partial a_j} \Delta a_j, \\ \Delta y_{Mj} = \frac{\partial y_{Mj}}{\partial a_j} \Delta a_j, \end{cases} \quad (2)$$

where  $\Delta a_j$  – length error,  $j$  – link:

$$\begin{cases} \frac{\partial x_M}{\partial a_j} = \frac{\partial a_9}{\partial a_j} + \frac{\partial a_7}{\partial a_j} \cos\varphi_4 - a_7 \sin\varphi_4 \frac{\partial \varphi_4}{\partial a_j} - EM \sin\gamma \cdot \left( \frac{\partial \gamma}{\partial a_j} \right), \\ \frac{\partial y_M}{\partial a_j} = \frac{\partial a_{10}}{\partial a_j} + \frac{\partial a_7}{\partial a_j} \sin\varphi_4 + a_7 \cos\varphi_4 \frac{\partial \varphi_4}{\partial a_j} + EM \cos\gamma \cdot \left( \frac{\partial \gamma}{\partial a_j} \right), \end{cases} \quad (j = 1, 2, 3, \dots, 13). \quad (3)$$

For finding of private derivatives  $\partial \varphi_i / \partial a_j$  in Eq. (3) we consider system of the equations:

$$\begin{cases} f_1 = a_9 + a_7 \cos\varphi_4 - a_5 \cos\varphi_3 - a_4 \cos\varphi_2 - a_3 \cos\varphi_1 = 0, \\ f_2 = a_{10} + a_7 \sin\varphi_4 - a_5 \sin\varphi_3 - a_4 \sin\varphi_2 - a_3 \sin\varphi_1 = 0, \\ f_3 = a_{11} + a_8 \cos\varphi_5 - a_6 \cos(\varphi_3 - \alpha) - a_4 \cos\varphi_2 - a_3 \cos\varphi_1 = 0, \\ f_4 = a_{12} + a_8 \sin\varphi_5 - a_6 \sin(\varphi_3 - \alpha) - a_4 \sin\varphi_2 - a_3 \sin\varphi_1 = 0, \end{cases} \quad (4)$$

and differentiate on  $a_j$ . From where we receive:

$$\frac{\partial f_k}{\partial a_j} = \frac{\partial f_k}{\partial \varphi_i} \cdot \frac{\partial \varphi_i}{\partial a_j}, \quad (k, i = 1, 2, 3, \dots, 5), \quad (j = 1, 2, 3, \dots, 13), \quad (5)$$

then:

$$\left( \frac{\partial \varphi_i}{\partial a_j} \right) = \left[ \frac{\partial f_k}{\partial \varphi_i} \right]^{-1} \cdot \left( \frac{\partial f_k}{\partial a_j} \right), \quad (6)$$

where:

$$\left( \frac{\partial f_k}{\partial \varphi_i} \right) = \begin{pmatrix} a_3 \sin\varphi_1 & a_4 \sin\varphi_2 & a_5 \sin\varphi_3 & -a_7 \sin\varphi_4 & 0 \\ -a_3 \cos\varphi_1 & -a_4 \cos\varphi_2 & -a_5 \cos\varphi_3 & a_7 \cos\varphi_4 & 0 \\ a_3 \sin\varphi_1 & a_4 \sin\varphi_2 & a_6 \sin(\varphi_3 - \alpha) & 0 & -a_8 \sin\varphi_5 \\ -a_3 \cos\varphi_1 & -a_4 \cos\varphi_2 & -a_6 \cos(\varphi_3 - \alpha) & 0 & a_8 \cos\varphi_5 \end{pmatrix}, \quad (7)$$

$$\left( \frac{\partial f_k}{\partial a_j} \right) = \begin{pmatrix} 0 & 0 & -\cos\varphi_1 & -\cos\varphi_2 & -\cos\varphi_3 & 0 & \cos\varphi_4 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -\sin\varphi_1 & -\sin\varphi_2 & -\sin\varphi_3 & 0 & \sin\varphi_4 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & -\cos\varphi_1 & -\cos\varphi_2 & 0 & B_{36} & 0 & \cos\varphi_5 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -\cos\varphi_1 & -\sin\varphi_2 & 0 & B_{46} & 0 & \sin\varphi_5 & 0 & 0 & 0 & 1 & 0 \end{pmatrix}, \quad (8)$$

$$B_{36} = \cos(\varphi_3 - \alpha) - \frac{a_5^2 - a_6^2 + a_{13}^2}{2a_5 a_6 m} \sin(\varphi_3 - \alpha),$$

$$B_{46} = \sin(\varphi_3 - \alpha) + \frac{a_5^2 - a_6^2 + a_{13}^2}{2a_5 a_6 m} \cos(\varphi_3 - \alpha),$$

$$m = \sqrt{1 - \left( \frac{a_5^2 + a_6^2 - a_{13}^2}{2a_5 a_6} \right)^2}.$$

We substitute the received values of private derivatives  $\partial\varphi_i/\partial a_j$  in equality Eq. (3), after that we define errors of the point position  $M$ .

The maximum error of the conrod point position  $M$  coming from errors in all metric parameters:

$$\begin{cases} \Delta x_{M\max} = \sum_{j=1}^{13} \left| \frac{\partial x_M}{\partial a_j} \right| \cdot |\Delta a_j|, \\ \Delta y_{M\max} = \sum_{j=1}^{13} \left| \frac{\partial y_M}{\partial a_j} \right| \cdot |\Delta a_j|, \end{cases} \quad (9)$$

$$\begin{cases} \Delta x_{M\max} = \sum_{j=1}^{13} \left| \frac{\partial a_9}{\partial a_j} + \frac{\partial a_7}{\partial a_j} \cos\varphi_4 - a_7 \sin\varphi_4 \frac{\partial \varphi_4}{\partial a_j} - EM \sin\gamma \cdot \left( \frac{\partial \gamma}{\partial a_j} \right) \right| \cdot |\Delta a_j|, \\ \Delta y_{M\max} = \sum_{j=1}^{13} \left| \frac{\partial a_{10}}{\partial a_j} + \frac{\partial a_7}{\partial a_j} \sin\varphi_4 + a_7 \cos\varphi_4 \frac{\partial \varphi_4}{\partial a_j} + EM \cos\gamma \cdot \left( \frac{\partial \gamma}{\partial a_j} \right) \right| \cdot |\Delta a_j|. \end{cases} \quad (10)$$

The algorithm of the solution of the task of the kinematic analysis of the third class mechanism is made on the basis of the derived formulas. The replacement of the rotary guide link on the progressive doesn't make essential changes to formulas of kinematic analysis. This technique was used at kinematic and dynamic investigations of concrete transform mechanism of the third class.

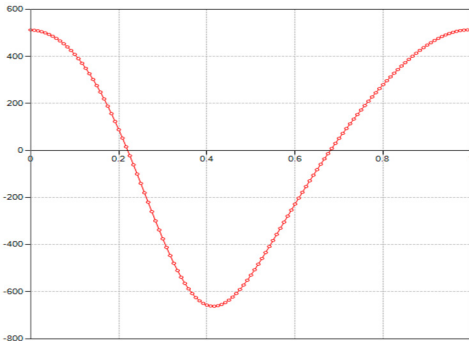


Fig. 2. Computed plot of the  $M$  point velocity module

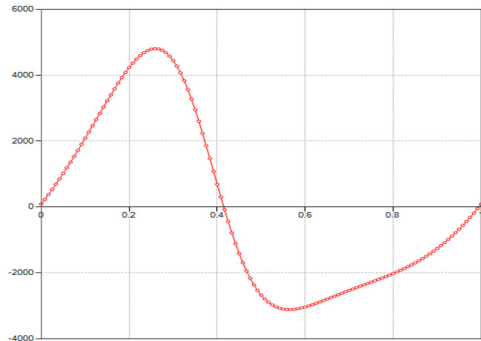


Fig. 3. Computed plot of the  $M$  point acceleration module

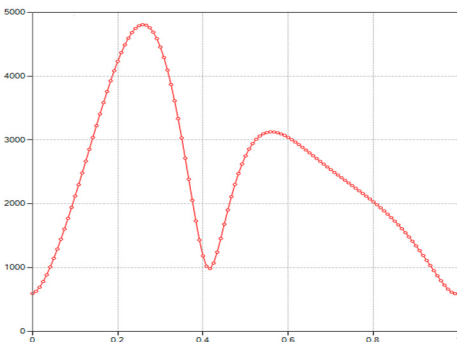


Fig. 4. Computed plot of the  $M$  point tangent acceleration module

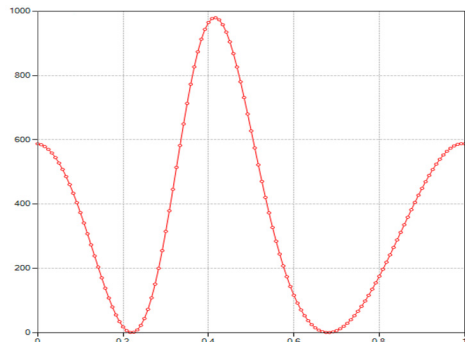


Fig. 5. Computed plot of the  $M$  point normal acceleration module

## 2. Results and discussion

In this paper, a kinematic model of the third class Assur group is presented. The method has the property of visibility, which makes it suitable for use in engineering practice. Simulation of the kinematical analysis of third class plain lever mechanism with output dwell is done using Model GIM software application that gives opportunity to develop discrete, continuous and hybrid models of complicated technical systems.

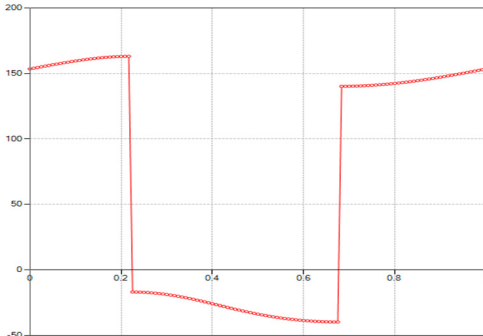


Fig. 6. Computed plot of the  $M$  point velocity  $\Phi$

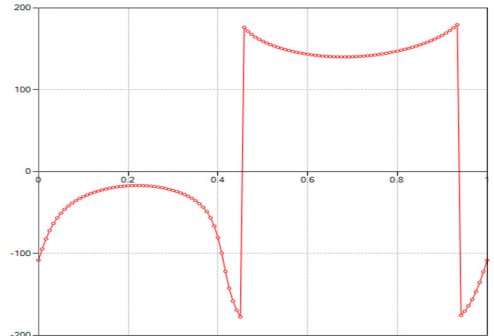


Fig. 7. Computed plot of the  $M$  point acceleration  $\Phi$

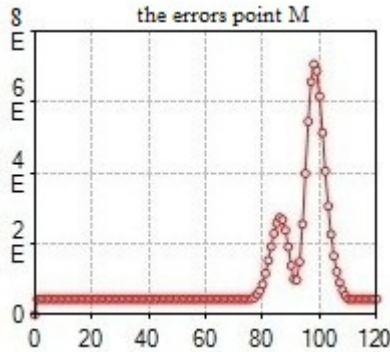


Fig. 8. Computed plot of the errors point  $M$

## 3. Conclusions

The combined analytic and graphic-analytical kinematic analysis method of the sixth class third order mechanism can be performed by accepting the inverse motion, considering the input element of the original mechanism as frame and one of the adjacent ternary element as drive element. The analysis of the mechanism is reduced to the study of third and second class Assur kinematic groups. The positional kinematic analysis shows that the most difficult problem is the solving of a trigonometric equations system by means of numerical methods. The kinematic analysis of a particular case indicated by Artobolevsky highlights the difficulties in computing the velocities in particular positions. However, some properties of the mechanism recommend it to be used in applications which need the preservation of parallel positions of the higher order couplers in self-locked extreme position and its compact size in folded position.

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