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DEFINITION OF POSITIONS AND SPEEDS OF LINKS OF MECHANISMS OF HIGH CLASSES

Abstract. In this work the analytical method of definition of positions and speeds of any mechanisms of high classes and an exact method of the kinematic analysis of transmission mechanisms of high classes are for the first time offered. The offered approach allowed developing the software according to the kinematic analysis of these mechanisms. The transmission mechanism of IV class is for the first time synthesized.

Keywords: kinematics, mechanism of high classes, position, speed.

1. Introduction. Mechanisms of high classes possess unique opportunities and properties of adaptation to external influences due to circulation of power on the closed contours. These mechanisms can maintain considerable power loadings, lift the mass of big size, operate many parameters, etc. Therefore the classification of mechanisms on the low and high classes offered by academicians I. I. Artobolevsky [1], U.A. Dzholdasbekov [2] has very important scientific and practical value. Originally it is necessary to carry any mechanisms with group of Assur of high classes and special to mechanisms of general purpose – the transfer, directing and moving mechanisms of high classes. Such classification allows developing the general theory of mechanisms of the first group for the purpose of detection of their functionality, and for the second – theoretical bases of calculation of kinematic, power and dynamic parameters and design of mechanisms with the set certain characteristics.

Further, these results can be used at design of lifting devices, working bodies of digging cars, robots with the closed contours, separate devices of aircraft, etc.

2. Kinematic analysis of the mechanism of high classes of general purpose. For the kinematic analysis of any mechanisms of high classes we use approach of work [3].

Statement of tasks. Let the mechanism of high classes consist of n of mobile links. Numbers of output links change from $\overline{1, n-m}$, and entrance from $j = \overline{n-m+1, n}$. Then the vector equations for the mechanism with group of Assur IV class with rotary couples and two degrees of freedom are representable in the form of (fig. 1).

$$\begin{aligned} &\vec{l}_1 + \vec{l}_2 + \vec{l}_3 + \vec{l}_5 - \vec{l}_6 - \vec{l}_0 = 0 \\ &\vec{l}_1^{\,*} + \vec{l}_3^{\,*} + \vec{l}_4 + \vec{l}_5 - \vec{l}_6 - \vec{l}_0 = 0 \end{aligned} \tag{1}$$

where $\vec{l}_i, \quad i = \overline{1,4}, \quad \vec{l}_j, \quad j = 5,6$. The Asterisk "*" means accessory of a vector $\vec{l}_i^{\,*}$ – to a basic link.

These equations (1) can be presented in projections to axes of motionless system of coordinates

$$\begin{aligned} &l_1 \cos\varphi_1 + l_2 \cos\varphi_2 + l_3 \cos\varphi_3 + l_5 \cos\varphi_5 - l_6 \cos\varphi_6 - l_0 \cos\varphi_0 = 0 \\ &l_1 \sin\varphi_1 + l_2 \sin\varphi_2 + l_3 \sin\varphi_3 + l_5 \sin\varphi_5 - l_6 \sin\varphi_6 - l_0 \sin\varphi_0 = 0 \\ &l_1^* \cos(\varphi_1 - \alpha_1) + l_3^* \cos(\varphi_3 - \alpha_3) + l_4 \cos\varphi_4 + l_5 \cos\varphi_5 - l_6 \cos\varphi_6 - l_0 \cos\varphi_0 = 0 \\ &l_1^* \sin(\varphi_1 - \alpha_1) + l_3^* \sin(\varphi_3 - \alpha_3) + l_4 \sin\varphi_4 + l_5 \sin\varphi_5 - l_6 \sin\varphi_6 - l_0 \sin\varphi_0 = 0 \end{aligned} \tag{2}$$

The task 1 is set. To find provisions of output links of the mechanism with group IV of a class of Assur at the set laws of the movement of entrance links and dimensional parameters of mechanisms of high classes:

$$\varphi_i = \varphi_i(\varphi_5, \varphi_6, P), \quad i = \overline{1,4}, \tag{3}$$

where $P = \{l_1, l_1^*, l_2, l_3, l_3^*, l_4, l_5, l_6, \alpha_1, \alpha_3, l_0, \varphi_0\}$, φ_5, φ_6 – the generalized angular coordinates, φ_i – angular coordinates of output links.

The vector form of record of kinematics equation is widely applied at research of lever mechanisms. Vector transformations accelerate process of an exception of variables, without passing to other forms of record of the equations of kinematics, such as system of the trigonometrical equations or system of the algebraic equations.

Analytical method of definition of positions and speeds of output links mechanism of the high classes. For vector approach from the first equation of system (3) we define $\vec{l}_2$, and from the second – $\vec{l}_4$ and further applying a scalar product, we have

$$\begin{aligned}
(\vec{l}_2)^2 &= (\vec{l}_1 + \vec{l}_3)^2 + 2(\vec{l}_1 + \vec{l}_3)(\vec{l}_5 - \vec{l}_6 - \vec{l}_0) + (\vec{l}_5 - \vec{l}_6 - \vec{l}_0)^2 \\
(\vec{l}_4)^2 &= (\vec{l}_1^* + \vec{l}_3^*)^2 + 2(\vec{l}_1^* + \vec{l}_3^*)(\vec{l}_5 - \vec{l}_6 - \vec{l}_0) + (\vec{l}_5 - \vec{l}_6 - \vec{l}_0)^2
\end{aligned} \tag{4}$$

After simple transformations of this system (4) for finding of vectors $\vec{l}_1$ and $\vec{l}_1^*$, we will receive special system of the scalar equations of a look:

$$\begin{aligned}
2(\vec{l}_3 + \vec{l}_5 - \vec{l}_6 - \vec{l}_0)\vec{l}_1 &= l_2^2 - l_1^2 - l_3^2 - (\vec{l}_5 - \vec{l}_6 - \vec{l}_0)^2 - 2\vec{l}_3(\vec{l}_5 - \vec{l}_6 - \vec{l}_0) \\
2(\vec{l}_3^* + \vec{l}_5 - \vec{l}_6 - \vec{l}_0)\vec{l}_1^* &= l_4^2 - l_1^* - l_3^{*2} - (\vec{l}_5 - \vec{l}_6 - \vec{l}_0)^2 - 2\vec{l}_3^*(\vec{l}_5 - \vec{l}_6 - \vec{l}_0)
\end{aligned} \tag{5}$$

Here it should be noted that it $\vec{l}_1^*$ is connected with $\vec{l}_1$, $\vec{l}_3^*$ and with $\vec{l}_3$, l_i – vector length, $\vec{l}_i$, $\vec{l}_i \cdot \vec{l}_i$ and $(\vec{l}_i + \vec{l}_j)^2$ are understood as scalar product of vectors. In this system angular coordinates φ_2, φ_4 of vectors $\vec{l}_2$ and $\vec{l}_4$ are excluded.

The last system in a scalar form has an appearance:

$$\begin{aligned}
A_1x_1 + B_1y_1 &= D_1 \\
A_2x_1 + B_2y_1 &= D_2 \\
x_1^2 + y_1^2 &= 1,
\end{aligned} \tag{6}$$

where

$x_1 = \cos(\varphi_1), y_1 = \sin(\varphi_1)$, $x_1^* = x_1 \cos\alpha_1 + y_1 \sin\alpha_1$, $y_1^* = x_1 \sin\alpha_1 - y_1 \cos\alpha_1$,

$x_3 = \cos(\varphi_3), y_3 = \sin(\varphi_3)$, $x_3^* = x_3 \cos\alpha_3 + y_3 \sin\alpha_3$, $y_3^* = x_3 \sin\alpha_3 - y_3 \cos\alpha_3$,

$x_4 = \cos(\varphi_4), y_4 = \sin(\varphi_4)$, $x_5 = \cos(\varphi_5), y_5 = \sin(\varphi_5)$, $x_6 = \cos(\varphi_6), y_6 = \sin(\varphi_6)$.

$A_1 = 2(l_3x_3 + l_5x_5 - l_6x_6 - l_0)l_1$, $B_1 = 2(l_3y_3 + l_5y_5 - l_6y_6)l_1$,

$D_1 = l_2^2 - l_1^2 - l_3^2 - (l_5x_5 - l_6x_6 - l_0)^2 - (l_5y_5 - l_6y_6)^2 -$
$- 2l_3x_3(l_5x_5 - l_6x_6 - l_0) - 2l_3y_3(l_5y_5 - l_6y_6)$,

$A_2 = 2(l_3^*x_3 + l_5x_5 - l_6x_6 - l_0)l_1^* \cos\alpha_1 - 2(l_3^*y_3 + l_5y_5 - l_6y_6)l_1^* \sin\alpha_1$,

$B_2 = 2(l_3^*x_3 + l_5x_5 - l_6x_6 - l_0)l_1^* \sin\alpha_1 + 2(l_3^*y_3 + l_5y_5 - l_6y_6)l_1^* \cos\alpha_1$,

$D_2 = l_4^2 - l_1^{*2} - l_3^{*2} - (l_5x_5 - l_6x_6 - l_0)^2 - (l_5y_5 - l_6y_6)^2 -$
$- 2l_3^*(l_5x_5 - l_6x_6 - l_0)x_3^* - 2l_3^*(l_5y_5 - l_6y_6)y_3^*$.

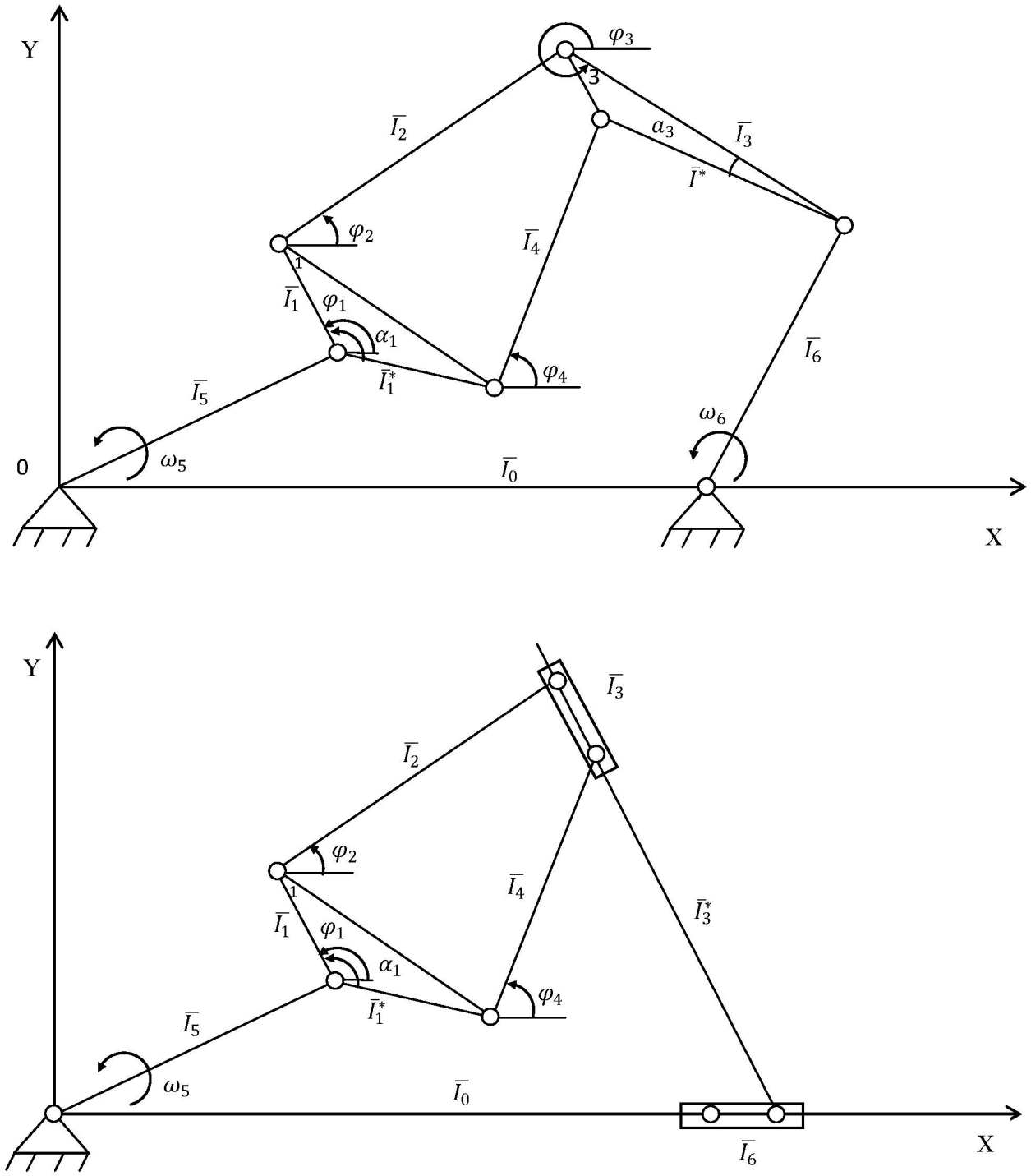

Figure 1 – Any mechanisms with group of Assur IV class

Originality of approach consists in transition from system (6) after application of universal substitution to system of quadratic equations:

$$(A_1 + D_1)u^2 - 2B_1u + D_1 + A_1 = 0 \tag{7}$$

$$(A_2 + D_2)u^2 - 2B_2u + D_2 - A_2 = 0.$$

It is originally necessary to define materiality of decisions of nonlinear system (6). For this purpose we will find discriminants of these equations (7).