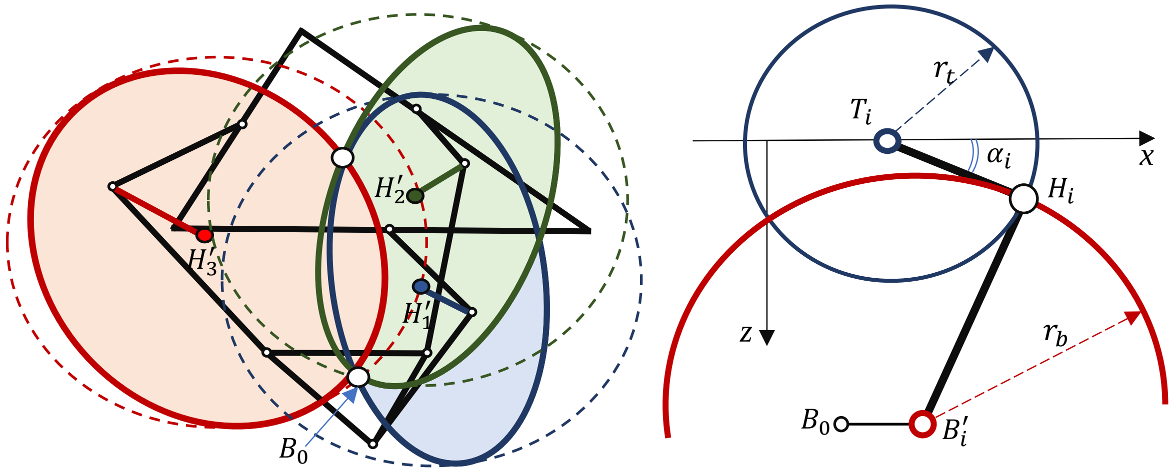
UDC 681.51/.54

G.G. Diachenko, O.O. Aziukovskyi, Ph.D., Associate Professor
(State Higher Educational Institution "National Mining University", Dnipro, Ukraine)

CONTROL LAW OF MOTION CONTROL OF A DELTA ROBOT ADAPTED TO DIGITAL SYSTEMS WITH NOT HIGH PERFORMANCE

The delta robot is a parallel robot, which means there is more than one kinematic chain from the base to the actuator of the robot [1]. It has three translational and one rotational degree of freedom. The basic idea is the use of a parallelogram. These parallelograms restrict the movement of the final platform for precise displacements. Only translational movements of the platform and its maintenance parallel to the base plane are allowed [2].



(a) Forward kinematics

(b) Inverse kinematics

Fig.1 - Kinematics

Kinematics of Delta robot. In this section, a summary of kinematics calculations is given.

In the inverse kinematics, as shown in Fig. 1(b), the position of H_i is calculated as the intersection of (1) and (2). The length H_iB_i' is the length of the x-z plane projection of H_iB_i and is calculated by (3). Then, each arm angle α_i is calculated by the position of H_i, as shown in (4).

$$\left(X_{H_i} - X_{T_i}\right)^2 + \left(Z_{H_i} - Z_{T_i}\right)^2 = |T_iH_i|^2, (1)$$

$$\left(X_{H_i} - X_{B_i'}\right)^2 + \left(Z_{H_i} - Z_{B_i'}\right)^2 = |H_iB_i'|^2, (2)$$

$$|H_iB_i'| = \sqrt{|B_iH_i|^2 - \left|B_iB_i'\right|^2}, (3)$$

$$\alpha_i = \arctan\left(Z_{H_i}/X_{H_i} - X_{T_i}\right). (4)$$

Such algebraic simplicity is obtained from a good choice of the reference frame for the case when $i = 1$. To keep this advantage and find the two remaining arm angles, the symmetry of deltas is used by means of the matrix (5), which rotates coordinates of the end-effector in the XY-Cartesian plane counter-clockwise through an angle θ ($\theta = 120°$ to get α_2 and $\theta = 240°$ to get α_3) round Z-axis with the help of transformation (6.1a):

$$R(-\theta) = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}, (5) \qquad \underset{i(\cdot),u(\cdot)}{R(-\theta)}: B_i \rightarrow B_i'. (6.1a)$$

$i \in [1:3]$, (6.1b) $u \in [u^-, u^+]$, (6.1c) $\psi(u) = \begin{cases} u^- : \mathrm{u} < u^- \\ u : u \in [u^-, u^+] \\ u^+ : \mathrm{u} > u^+ \end{cases}$, (6.1d)

with vertexes of bottom delta $B_i \in \mathbb{R}^2$ subject to box constraints (6.1b) and (6.1c) via (6.1d).

In the forward kinematics, as shown in Fig. 1(a), the point H_i is calculated based on reference for α_i. The end position B_0 is calculated as the intersection of the three sphere equations centring in H_i'. The equations are as follows:

$$\left(x - x_{H_1'}\right)^2 + \left(y - y_{H_1'}\right)^2 + \left(z - z_{H_1'}\right)^2 - r_b^2 = 0,$$
$$\left(x - x_{H_2'}\right)^2 + \left(y - y_{H_2'}\right)^2 + \left(z - z_{H_2'}\right)^2 - r_b^2 = 0,$$
$$\left(x - x_{H_3'}\right)^2 + \left(y - y_{H_3'}\right)^2 + \left(z - z_{H_3'}\right)^2 - r_b^2 = 0.$$

References:

[1] Diachenko, G. G., and Aziukovskyi, O. O. (2018). CONTROL LAWS OF ELECTRIC DRIVES AS A RESULT OF AN IN-DEPTH KINEMATIC ANALYSIS OF THE DELTA ROBOT. *Scientific Bulletin of National Mining University*, (1), 106-112.

[2] S. Stan, M. Manic, C. Szep and R. Balan (2011). Performance analysis of 3 DOF Delta parallel robot. *2011 4th International Conference on Human System Interactions, HSI 2011*, Yokohama, 215-220.