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DEPENDENCE RELATIONS BETWEEN THE INITIAL AND FINAL POSITIONS OF TRTRR1 ROBOT FOR THE MANIPULATION OF FLANGES

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Abstract: *The work shall be submitted the calculation algorithm for the study positions occupied by flanges handled by the robot TRTTR1. This is the case, it shall consider the robot kinematic diagram industrial TRTTR1 for which it is to apply theory finished movements, with a view to the establishment of the dependence relations between initial and final positions occupied from the flange.*

Keywords: *TRTTR1 robot, finite displacement theory, flanges manipulation law.*

1. GENERAL KNOWLEDGES

In this work, the calculation algorithm for the study positions occupied by flanges handled by the robot TRTTR1. This is the case it shall consider the kinematics diagram of the industrial TRTTR1 robot shown in figure 1.

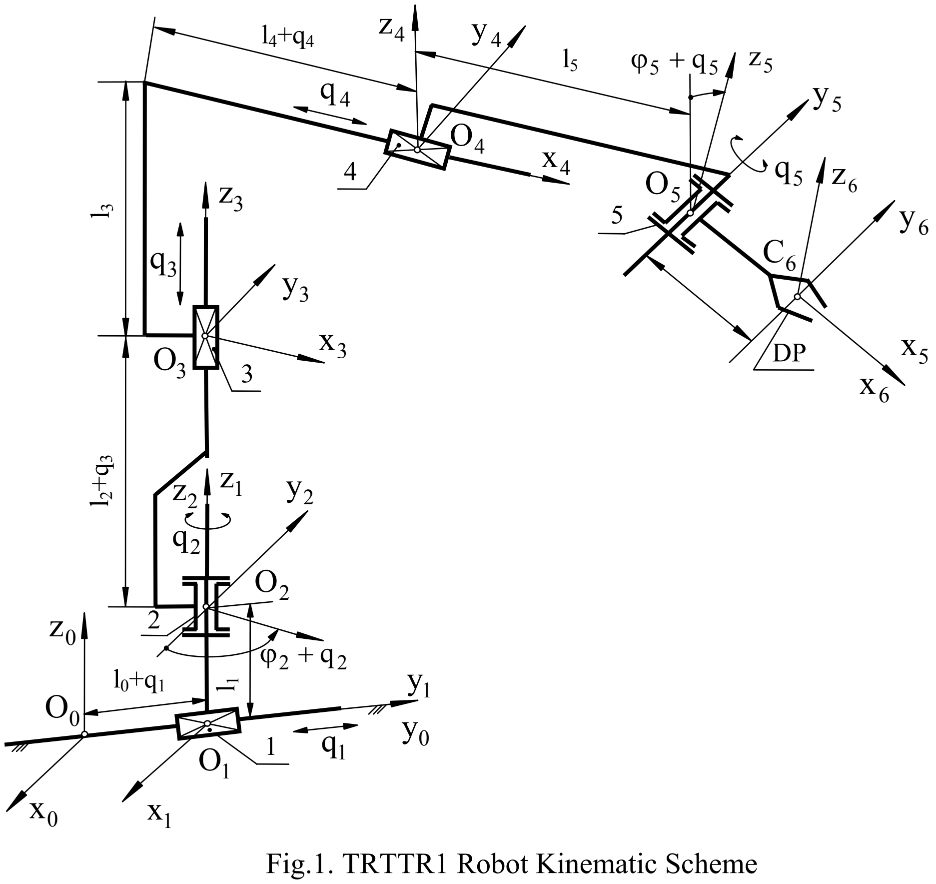

Fig.1. TRTTR1 Robot Kinematic Scheme

The constructive parameters of the TRTTR1 robot are l_0, l_i ($i=1\div6$), φ_2, φ_5, and the geometric parameters of the robot motion are q_k ($k=1\div5$). The TRTTR1 robot can be considered in zero position given by the constructive parameters l_0, l_i ($i=1\div6$), φ_2, φ_5.

In a fixed point A_0 belonging to TRTTR1 robot base introduce fixed system $A_0x_0y_0z_0$, and at the points O_i, considered as centres of gravity of modules, ($i=1\div5$), introduce 5 reference systems mobile $O_ix_iy_iz_i$, as shown in figure 1.

In the case of this problem, given its initial position of the flange attached to the device by the robot prehensive by the co-ordinates of the three-point hitch nocollinear belonging to flange, recorded from mobile system $O_5x_5y_5z$) jointly and severally liable with the prehensive device, shall be required to determine the position of the flange end laid down by the co-ordinates these same three points recorded from the system fixed at the base robot, if known geometric-cinematic and constructive parameters of robot [Isp03], [Isp90], [Pop85].

Using relationships to transition from a mobile reference system to the other, and finished movements of the theory, it may solve this problem. Namely, achieve a matrix relationship of dependence between start and end positions of flange, of which shall be determined coordinates of the three points in the final position.

2. APPLICATION OF FINITE DIPLACEMETS THEORY TO THE TRTTR1 ROBOT

For the purposes of applying the finished displacements theory To rigid solid must start and end positions of flange handled by robot to be reported to the same reference system. This is achieved by using the transformation matrix relations of the coordinates from a reference system to another.

Initial position of the flange recorded from the system $O_5x_5y_5z_5$ is determined from the matrix relationship:

$$[r_1(i)]_5 = [r_0 \vdots C]_{56} \cdot [r_1(i)]_6, \tag{1}$$

in which

$$[r_1(i)]_5 = \begin{bmatrix} 1 \\ x_1(i)_5 \\ y_1(i)_5 \\ z_1(i)_5 \end{bmatrix}; \quad [r_1(i)]_6 = \begin{bmatrix} 1 \\ x_1(i)_6 \\ y_1(i)_6 \\ z_1(i)_6 \end{bmatrix} \tag{2}$$

They represent unicolumn of the coordinate for the flange points in the initial position recorded the systems $O_5x_5y_5z_5$, $A_6x_6y_6z_6$;

$$[r_0 \vdots C]_{56} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ l_6 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

Is the transformation matrix of the point coordinates from the system $O_6x_6y_6z_6$ at the system $O_5x_5y_5z_5$.

Final Position of the flange after rotation around the axis O_5y_5, is given by the relationship matrix, given by [Isp04] as:

$$[r_2(i)]_5 = [R]_5 \cdot [r_1(i)]_5, \quad (i=1, 2, 3), \tag{4}$$

having:

$$[r_2(i)]_5 = \begin{bmatrix} 1 \\ x_2(i)_5 \\ y_2(i)_5 \\ z_2(i)_5 \end{bmatrix} \tag{5}$$

which means the matrix column of points coordinates of flange in final position after rotation around the axis O_5y_5, and:

$$[r_1(i)]_5 = \begin{bmatrix} 1 \\ x_1(i)_5 \\ y_1(i)_5 \\ z_1(i)_5 \end{bmatrix} \tag{6}$$

is the matrix column in the coordinates of the 3 points in the initial position recorded from the system $O_5x_5y_5z_5$, but:

$$[R]_5 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & cq_5 & 0 & sq_5 \\ 0 & 0 & 1 & 0 \\ 0 & -sq_5 & 0 & cq_5 \end{bmatrix} \tag{7}$$

is the rotation matrix.

To achieve translation characterized by parameter q_4 in along the axis O_4x_4, and the start and the end positions of flange must be recorded from the system $O_4x_4y_4z_4$. So, it can be written for the processing matrix of relationship:

$$[r_1(i)]_4 = [r_0 \vdots C]_{45} \cdot [r_2(i)]_5, \tag{8}$$

in which

$$[r_1(i)]_4 = \begin{bmatrix} 1 \\ x_1(i)_4 \\ y_1(i)_4 \\ z_1(i)_4 \end{bmatrix} \tag{9}$$

is the matrix column of the flange points coordinates recorded from the system $O_4x_4y_4z_4$, considered in its initial position, and

$$[r_0 \vdots C]_{45} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ l_5 & c\varphi_5 & 0 & s\varphi_5 \\ 0 & 0 & 1 & 0 \\ 0 & -s\varphi_5 & 0 & c\varphi_5 \end{bmatrix} \tag{10}$$

is the transformation matrix of the coordinates from the system $O_5x_5y_5z_5$ to the system $O_4x_4y_4z_4$.

By applying the calculation algorithm to the problem of reverse of finite displacements are obtained, the coordinates $x_2(i)_4, y_2(i)_4$, $z_2(i)_4$, i=1, 2, 3, of the three points of flange handled by robot, after its translation along the axis O_4x_4 with dimension l_5. The relationship matrix which characterises this movement is:

$$[r_2(i)]_4 = [r_0 \vdots C]_4 \cdot [r_1(i)]_4, \quad i=1, 2, 3. \tag{11}$$

In the relationship (10) specify the matrices as follows:

$$[r_2(i)]_4 = \begin{bmatrix} 1 \\ x_2(i)_4 \\ y_2(i)_4 \\ z_2(i)_4 \end{bmatrix}, [r_1(i)]_4 = \begin{bmatrix} 1 \\ x_1(i)_4 \\ y_1(i)_4 \\ z_1(i)_4 \end{bmatrix}, i=1, 2, 3 \tag{12}$$

which means column matrices of the points coordinates of flange recorded from the system $O_4x_4y_4z_4$ in final and initial positions;

$$[r_0 \vdots C]_4 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ q_4 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{13}$$

represents the translation matrix in along the axis O_4x_4.

To be able to carry out rototranslation around and along the axis A_2z_2, is carried out a change from the system $O_4x_4y_4z_4$ to the system $O_2x_2y_2z_2$. The relationship matrix which characterizes such passage is as follows:

$$[r_1(i)]_2 = [r_0 \vdots C]_{24} \cdot [r_2(i)]_4. \tag{14}$$

In this relationship made the following points:

$$[r_1(i)]_2 = \begin{bmatrix} 1 \\ x_1(i)_2 \\ y_1(i)_2 \\ z_1(i)_2 \end{bmatrix} \tag{15}$$

is the column matrix of the points coordinates belong to the flange recorded from the system $O_2x_2y_2z_2$, considered in the initial position;

$$[r_0 \vdots C]_{24} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ l_4 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ l_2 + l_3 & 0 & 0 & 1 \end{bmatrix} \tag{16}$$

is the transformation matrix of the points coordinates of flange from the system $O_4x_4y_4z_4$ to the system $O_2x_2y_2z_2$.

The relationship matrix which characterizes the movement rototranslation around and along the axis O_2z_2 is as follows:

$$[r_2(i)]_2 = [r_0 \vdots C]_2 \cdot [r_1(i)]_2, \quad i=1, 2, 3. \tag{17}$$

The meanings of matrix relationship (17) are as follows:

$$\left[r_2(i)\right]_2 = \begin{bmatrix} 1 \\ x_2(i)_2 \\ y_2(i)_2 \\ z_2(i)_2 \end{bmatrix} \tag{18}$$

is the matrix column of the flange points coordinates in final position after roto-translation around and along the axis O_2z_2, which is characterized by the parameters geometric-cinematic q_2 and q_3;

$$\left[r_0 \vdots C\right]_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & cq_2 & -sq_2 & 0 \\ 0 & sq_2 & cq_2 & 0 \\ q_3 & 0 & 0 & 1 \end{bmatrix}, \tag{19}$$

is the screw matrix.

To determine the position of the flange registered about the fixed final system $A_0x_0y_0z_0$ at the base robot, it is necessary to start a transformation of flange points coordinates from the system $O_2x_2y_2z_2$ to the system $A_0x_0y_0z_0$. This relationship has the form:

$$\left[r_1(i)\right]_0 = \left[r_0 \vdots C\right]_{02} \cdot \left[r_2(i)\right]_2, \quad i=1, 2, 3, \tag{20}$$

in which

$$\left[r_1(i)\right]_0 = \begin{bmatrix} 1 \\ x_1(i)_0 \\ y_1(i)_0 \\ z_1(i)_0 \end{bmatrix}, \tag{21}$$

is the matrix column of the flange points coordinates recorded from the system $A_0x_0y_0z_0$, flange being considered in the initial position;

$$\left[r_0 \vdots C\right]_{02} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & c\varphi_2 & -s\varphi_2 & 0 \\ l_0 & s\varphi_2 & c\varphi_2 & 0 \\ l_1 & 0 & 0 & 1 \end{bmatrix} \tag{22}$$

is the transformation matrix of the flange points coordinates.

The relationship matrix which characterizes the translation motion along the axis A_0y_0 and leading to determination of final position of the flange is as follows:

$$\left[r_2(i)\right]_0 = \left[r_0 \vdots C\right]_0 \cdot \left[r_1(i)\right]_0, \quad i=1, 2, 3. \tag{23}$$

In this relation there are the following points:

$$\left[r_2(i)\right]_0 = \begin{bmatrix} 1 \\ x_2(i)_0 \\ y_2(i)_0 \\ z_2(i)_0 \end{bmatrix} \tag{24}$$

is the matrix column of flange points coordinates manipulated by robot in final position, which is recorded from the fixed system $A_0x_0y_0z_0$;

$$\left[r_0 \vdots C\right]_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ q_1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{25}$$

is the translation matrix along the O_0y_0 axis.

Having regard to relations (20), (17), (14), (11), (8), (5) and (1), relationship (25) reaches form:

$$\left[r_2(i)\right]_0 = \left[r_0 \vdots C\right]_0 \cdot {}^{7}\left[\left[r_0 \vdots C\right]_{02} \cdot {}^{6}\left[\left[r_0 \vdots C\right]_2 \cdot {}^{5}\left[\left[r_0 \vdots C\right]_{24} \cdot {}^{4}\left[\left[r_0 \vdots C\right]_4 \cdot {}^{3}\left[\left[r_0 \vdots C\right]_{45} \cdot {}^{2}\left[\left[R\right]_5 \cdot {}^{1}\left[\left[r_0 \vdots C\right]_{56} \cdot \left[r_1(i)\right]_6\right]^{1}\right]^{2}\right]^{3}\right]^{4}\right]^{5}\right]^{6}\right]^{7}$$

$$i=1,2,3. \tag{26}$$

The expressions of the flange points coordinates handled by robot in final position in accordance with (25), (22), (19), (16), (13), (10), (7), (3) and (2), shall be determined successively calculations performed in the relationship matrix (26). So:

$$[r_2(i)]_0 = \begin{bmatrix} 1 \\ x_2(i)_0 \\ y_2(i)_0 \\ z_2(i)_0 \end{bmatrix} =$$

$$= \left[\begin{array}{l} 1 \\ \hline q_4 cq_2 c\varphi_2 + l_4 cq_2 c\varphi_2 + l_5 cq_2 c\varphi_2 + l_6 cq_5 cq_2 c\varphi_5 c\varphi_2 + x_1(i)_6 cq_2 cq_5 c\varphi_5 c\varphi_2 + \\ \quad + z_1(i)_6 sq_5 cq_2 c\varphi_5 c\varphi_2 - l_6 sq_5 cq_2 s\varphi_5 c\varphi_2 - x_1(i)_6 sq_5 cq_2 s\varphi_5 c\varphi_2 + \\ \quad + z_1(i)_6 cq_5 cq_2 s\varphi_5 c\varphi_2 - y_1(i)_6 sq_2 c\varphi_2 - q_4 sq_2 s\varphi_2 - l_4 sq_2 s\varphi_2 - l_5 sq_2 s\varphi_2 - \\ \quad - l_6 cq_5 sq_2 c\varphi_5 s\varphi_2 - x_1(i)_6 sq_2 cq_5 c\varphi_5 s\varphi_2 - z_1(i)_6 sq_5 sq_2 c\varphi_5 s\varphi_2 + \\ \quad + l_6 sq_5 sq_2 s\varphi_5 s\varphi_2 + x_1(i)_6 sq_5 sq_2 s\varphi_5 s\varphi_2 - z_1(i)_6 cq_5 sq_2 s\varphi_5 s\varphi_2 - y_1(i)_6 cq_2 s\varphi_2 \\ \hline q_1 + l_0 + q_4 cq_2 s\varphi_2 + l_4 cq_2 s\varphi_2 + l_5 cq_2 s\varphi_2 + l_6 cq_5 cq_2 c\varphi_5 s\varphi_2 + x_1(i)_6 cq_2 cq_5 c\varphi_5 s\varphi_2 + \\ \quad + z_1(i)_6 sq_5 cq_2 c\varphi_5 s\varphi_2 - l_6 sq_5 cq_2 s\varphi_5 s\varphi_2 - x_1(i)_6 sq_5 cq_2 s\varphi_5 s\varphi_2 + \\ \quad + z_1(i)_6 cq_5 cq_2 s\varphi_5 s\varphi_2 - y_1(i)_6 sq_2 s\varphi_2 + q_4 sq_2 c\varphi_2 + l_4 sq_2 c\varphi_2 + l_5 sq_2 c\varphi_2 + \\ \quad + l_6 cq_5 sq_2 c\varphi_5 c\varphi_2 + x_1(i)_6 sq_2 cq_5 c\varphi_5 c\varphi_2 + z_1(i)_6 sq_5 sq_2 c\varphi_5 c\varphi_2 - \\ \quad - l_6 sq_5 sq_2 s\varphi_5 c\varphi_2 - x_1(i)_6 sq_5 sq_2 s\varphi_5 c\varphi_2 + z_1(i)_6 cq_5 sq_2 s\varphi_5 c\varphi_2 + y_1(i)_6 cq_2 c\varphi_2 \\ \hline q_3 + l_1 + l_2 + l_3 - l_6 cq_5 s\varphi_5 - x_1(i)_6 cq_5 s\varphi_5 - z_1(i)_6 sq_5 s\varphi_5 - l_6 sq_5 c\varphi_5 - \\ \quad - x_1(i)_6 sq_5 c\varphi_5 + z_1(i)_6 cq_5 c\varphi_5 \end{array} \right], \tag{27}$$

$$\begin{aligned} x_2(i)_0 &= x_1(i)_6 (cq_2 cq_5 c\varphi_5 c\varphi_2 - sq_5 cq_2 s\varphi_5 c\varphi_2 - sq_2 cq_5 c\varphi_5 s\varphi_2 + sq_5 sq_2 s\varphi_5 s\varphi_2) - \\ &- y_1(i)_6 (sq_2 c\varphi_2 + cq_2 s\varphi_2) + z_1(i)_6 (sq_5 cq_2 c\varphi_5 c\varphi_2 + cq_5 cq_2 s\varphi_5 c\varphi_2 - sq_5 sq_2 c\varphi_5 s\varphi_2 - \\ &- cq_5 sq_2 s\varphi_5 s\varphi_2) + q_4 (cq_2 c\varphi_2 - sq_2 s\varphi_2) + l_4 (cq_2 c\varphi_2 - sq_2 s\varphi_2) + l_5 (cq_2 c\varphi_2 - sq_2 s\varphi_2) + \\ &+ l_6 (cq_5 cq_2 c\varphi_5 c\varphi_2 - sq_5 cq_2 s\varphi_5 c\varphi_2 - cq_5 sq_2 c\varphi_5 s\varphi_2 + sq_5 sq_2 s\varphi_5 s\varphi_2); \quad i = 1, 2, 3. \\ x_2(i)_0 &= x_1(i)_6 (cq_2 cq_5 c\varphi_5 c\varphi_2 - sq_5 cq_2 s\varphi_5 c\varphi_2 - sq_2 cq_5 c\varphi_5 s\varphi_2 + sq_5 sq_2 s\varphi_5 s\varphi_2) - \\ &- y_1(i)_6 (sq_2 c\varphi_2 + cq_2 s\varphi_2) + z_1(i)_6 (sq_5 cq_2 c\varphi_5 c\varphi_2 + cq_5 cq_2 s\varphi_5 c\varphi_2 - sq_5 sq_2 c\varphi_5 s\varphi_2 - \\ &- cq_5 sq_2 s\varphi_5 s\varphi_2) + q_4 (cq_2 c\varphi_2 - sq_2 s\varphi_2) + l_4 (cq_2 c\varphi_2 - sq_2 s\varphi_2) + l_5 (cq_2 c\varphi_2 - sq_2 s\varphi_2) + \\ &+ l_6 (cq_5 cq_2 c\varphi_5 c\varphi_2 - sq_5 cq_2 s\varphi_5 c\varphi_2 - cq_5 sq_2 c\varphi_5 s\varphi_2 + sq_5 sq_2 s\varphi_5 s\varphi_2); \quad i = 1, 2, 3. \\ z_2(i)_0 &= -x_1(i)_6 (cq_5 s\varphi_5 + sq_5 c\varphi_5) - z_1(i)_6 (sq_5 s\varphi_5 - cq_5 c\varphi_5) - l_6 (cq_5 s\varphi_5 + sq_5 c\varphi_5) + q_3 + l_1 + l_2 + l_3 . \text{i=1, 2, 3.} \end{aligned} \tag{28}$$

3. CONCLUSIONS

With the help of relations (28) and in accordance with [Isp79a] and [Pop85], cells can be set up for flexible manufacturing marks the flange type, namely, the following may be determined positions tools machinery and auxiliary devices of cell structure. They can be carried out as follows:

1. Flange located on a conveyor belt to position the grip of the robot shall be considered in the initial position.
2. Through the application of relations (28) shall be determined final position of the flange, imposing robot movements in couplers which define the position of first implement cell structure.
3. Flange secured in position universal first machine tools, is considered as initial position for the application finished following movements which would lead to define the position of the second machine in the framework of the manufacturing cell.

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RELAŢII DE DEPENDENŢĂ ÎNTRE POZIŢIILE INIŢIALĂ ŞI FINALĂ A FLANŞEI MANIPULATĂ DE CĂTRE ROBOTUL TRTTR1

Rezumat: În această lucrare, se prezintă algoritmul de calcul pentru studiul poziţiilor ocupate de flanşele manipulate de către robotul TRTTR1. În acest sens, se consideră schema cinematică a robotului industrial TRTTR1 pentru care se aplică teoria deplasărilor finite, în vederea stabilirii relaţiilor de dependenţa între poziţiile iniţială şi finală ocupate de flanşă.

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