



FLEXIBLE CELL FOR LARGE FLANGES PROCESSING

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Abstract: The work presents a flexible cell by the manufacturer with machining centers situated in the same part of the robot for the large flange processing. Presenting the case with processing centers of the same operations located on the left side of the robot. Shall be submitted, shall be investigated and didactic norm is settled designing and geometrical-kinematics parameters across phases. Case presented is unique in the literature, for this type of processing centers.

Keywords: flexible cell, processing centres, robot left hand side.

1. INTRODUCTION

Below is the operating cycle of TRTRR robot, in a cell with flexible machining centers for the same operation located on the left hand side of the robot in the zero position, in accordance with [ISP81], [Kha02], [San99]. In the case of this variants are deploy two robots TRTRR type.

2. THE OPERATING CYCLE

The operating cycle of the two robots within flexible cell is as follows:

1. First flanged connection shall enter on the power strip and the robot one is located in the rest position. It takes subsequently flange on the conveyor belt (Fig. 1) and inserts it into universal first lathe. On CNC1 these operations are carried out by lathing, roughing and finishing. For this phase of the operating cycle of the robot, it may be appropriate and following designed and kinematics parameters:

$$l_1=150\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; l_5 = 450 \text{ mm}; l_6 = 100 \text{ mm}; l_7 = 300 \text{ mm}; l_8 = - 50 \text{ mm}; \varphi_2 = 65^\circ; \varphi_4 = 0^\circ; \varphi_5 = 90^\circ; q_1 = 350 \text{ mm}; q_2 = 70^\circ; q_3 = 0 \text{ mm}; q_4 = 90^\circ; q_5 = 0^\circ. \quad (1)$$

Numbered points from 1-11 in figure 1 represents movements made by robot after data values given designed and kinematics parameters.

In accordance with relationships

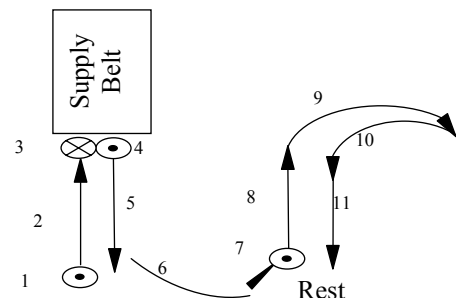


Fig.1. Procession Cycle: First phase

established for the robot TRTTR, he wrote as follows (relation 2), and the characteristic points considered to 6 fixed reference system (Fig. 2.), as defined by the relationship (3).

$$l_1 = 150 \text{ mm}; l_2 = 200 \text{ mm}; l_3 = 350 \text{ mm}; l_4 = 0 \text{ mm}; l_5 = 450 \text{ mm}; l_6 = 100 \text{ mm}; l_7 = 300 \text{ mm}; l_8 = - 50 \text{ mm}; q_1 = 0 - 400 \text{ mm}; q_2 = 0 - 270^\circ; q_3 = 0 - 800 \text{ mm}; q_4 = 0 - 360^\circ; q_5 = 0 - 270^\circ, \varphi_2 = 0 - 360^\circ; \varphi_4 = 0 - 90^\circ; \varphi_5 = 0 - 90^\circ. \quad (3)$$

$$\begin{aligned}
 x_2(i)_0 = & x_1(i)_6 (cq_4cp_4cp_2cq_2 - sq_4sp_4cp_2cq_2 - cq_4cp_4sp_2sq_2 + sq_4sp_4sp_2sq_2) + \\
 & + y_1(i)_6 (cq_5sp_5sq_4cp_4cp_2cq_2 + sq_5cp_5sq_4cp_4cp_2cq_2 + cq_5sp_5cp_4sp_4cp_2cq_2 + \\
 & + sq_5cp_5cp_4sp_4cp_2cq_2 - cq_5cp_5sp_2cq_2 + sq_5sp_5sp_2cq_2 - cq_5sp_5sq_4cp_4sp_2sq_2 - \\
 & - sq_5cp_5sq_4cp_4sp_2sq_2 - cq_5sp_5cp_4sp_4sp_2sq_2 - sq_5cp_5cp_4sp_4sp_2sq_2 - cq_5cp_5cp_2sq_2 + \\
 & + sq_5sp_5cp_2sq_2) - z_1(i)_6 (sq_5sp_5sq_4cp_4cp_2cq_2 - cq_5cp_5sq_4cp_4cp_2cq_2 + sq_5sp_5cp_4sp_4cp_2cq_2 - \\
 & - cq_5cp_5cp_4sp_4cp_2cq_2 - sq_5cp_5sp_2cq_2 - cq_5sp_5sp_2cq_2 - sq_5sp_5sq_4cp_4sp_2sq_2 + \\
 & + cq_5cp_5sq_4cp_4sp_2sq_2 - sq_5sp_5cp_4sp_4sp_2sq_2 + cq_5cp_5cp_4sp_4sp_2sq_2 - sq_5cp_5cp_2sq_2 - \\
 & - cq_5sp_5cp_2sq_2) + l_8 (-cq_4cp_4cp_2cq_2 + sq_4sp_4cp_2cq_2 + cq_4cp_4sp_2sq_2 - sq_4sp_4sp_2sq_2) + \\
 & + l_7 (cq_5sp_5sq_4cp_4cp_2cq_2 + sq_5cp_5sq_4cp_4cp_2cq_2 + cq_5sp_5cp_4sp_4cp_2cq_2 + \\
 & + sq_5cp_5cp_4sp_4cp_2cq_2 - cq_5cp_5sp_2cq_2 + sq_5sp_5sp_2cq_2 - cq_5sp_5sq_4cp_4sp_2sq_2 - \\
 & - sq_5cp_5sq_4cp_4sp_2sq_2 - cq_5sp_5cp_4sp_4sp_2sq_2 - sq_5cp_5cp_4sp_4sp_2sq_2 - cq_5cp_5cp_2sq_2 + \\
 & + sq_5sp_5cp_2sq_2) - q_3 (sp_2cq_2 + cp_2sq_2) - l_5 (sp_2cq_2 + cp_2sq_2) - l_6 (sp_2cq_2 + cp_2sq_2) - l_4sq_2,
 \end{aligned}$$

$$\begin{aligned}
 y_2(i)_0 = & x_1(i)_6 (cq_4cp_4cp_2sq_2 - sq_4sp_4cp_2sq_2 + cq_4cp_4sp_2cq_2 - sq_4sp_4sp_2cq_2) + \\
 & + y_1(i)_6 (cq_5sp_5sq_4cp_4cp_2sq_2 + sq_5cp_5sq_4cp_4cp_2sq_2 + cq_5sp_5cp_4sp_4cp_2sq_2 + \\
 & + sq_5cp_5cp_4sp_4cp_2sq_2 - cq_5cp_5sp_2sq_2 + sq_5sp_5sp_2sq_2 + cq_5sp_5sq_4cp_4sp_2cq_2 + \\
 & + sq_5cp_5sq_4cp_4sp_2cq_2 + cq_5sp_5cp_4sp_4sp_2cq_2 + sq_5cp_5cp_4sp_4sp_2cq_2 + \\
 & + cq_5cp_5cp_2cq_2 - sq_5sp_5cp_2cq_2) + z_1(i)_6 (-sq_5sp_5sq_4cp_4cp_2sq_2 + \\
 & + cq_5cp_5sq_4cp_4cp_2sq_2 - sq_5sp_5cp_4sp_4cp_2sq_2 + cq_5cp_5cp_4sp_4cp_2sq_2 + \\
 & + sq_5cp_5sp_2sq_2 + cq_5sp_5sp_2sq_2 - sq_5sp_5sq_4cp_4sp_2cq_2 + cq_5cp_5sq_4cp_4sp_2cq_2 - \\
 & - sq_5sp_5cp_4sp_4sp_2cq_2 + cq_5cp_5cp_4sp_4sp_2cq_2 - sq_5cp_5cp_2cq_2 - cq_5sp_5cp_2cq_2) + \\
 & + l_8 (-cq_4cp_4cp_2sq_2 + sq_4sp_4cp_2sq_2 - cq_4cp_4sp_2cq_2 + sq_4sp_4sp_2cq_2) + \\
 & + l_7 (cq_5sp_5sq_4cp_4cp_2sq_2 + sq_5cp_5sq_4cp_4cp_2sq_2 + cq_5sp_5cp_4sp_4cp_2sq_2 + \\
 & + sq_5cp_5cp_4sp_4cp_2sq_2 - cq_5cp_5sp_2sq_2 + sq_5sp_5sp_2sq_2 + cq_5sp_5sq_4cp_4sp_2cq_2 + \\
 & + sq_5cp_5sq_4cp_4sp_2cq_2 + cq_5sp_5cp_4sp_4sp_2cq_2 + sq_5cp_5cp_4sp_4sp_2cq_2 + \\
 & + cq_5cp_5cp_2cq_2 - sq_5sp_5cp_2cq_2) + q_3 (-sp_2sq_2 + cp_2cq_2) + l_5 (-sp_2sq_2 + cp_2cq_2) + \\
 & + l_6 (-sp_2sq_2 + cp_2cq_2) + l_4cq_2,
 \end{aligned}$$

$$\begin{aligned}
 z_2(i)_0 = & -x_1(i)_6 (cq_4sp_4 + sq_4cp_4) + y_1(i)_6 (-cq_5sp_5sq_4sp_4 - sq_5cp_5sq_4sp_4 + cq_5sp_5cp_4cp_4 + \\
 & + sq_5cp_5cp_4cp_4) + z_1(i)_6 (sq_5sp_5sq_4sp_4 - cq_5cp_5sq_4sp_4 - sq_5sp_5cp_4cp_4 + cq_5cp_5cp_4cp_4) + \\
 & + l_8 (cq_4sp_4 + sq_4cp_4) + l_7 (-cq_5sp_5sq_4sp_4 - sq_5cp_5sq_4sp_4 + cq_5sp_5cp_4cp_4 + \\
 & + sq_5cp_5cp_4cp_4) + q_1 + l_1 + l_2 + l_3.
 \end{aligned}$$

i = 1, 2, 3. (2)

Reaching the final position at the base robot, there is.

$$M(1)_6=(0,0,0), M(2)_6=(100,0,0), M(3)_6=(0,0,100), \tag{4}$$

The coordinates of points flange end position have been determined using the Calculation program Matlab 7.1, in accordance with [ISP81], [PLI84], [MAR93] and [Man01]. After calculations, the coordinates (i=1, 2, 3) in final position have the following values:

$$x_2(1)_0 = -955,90 \text{ mm}; y_2(1)_0 = -955,02 \text{ mm};$$

$$z_2(1)_0 = 1000 \text{ mm}; i = 1,$$

$$x_2(2)_0 = -964,97 \text{ mm}; y_2(2)_0 = -960,17 \text{ mm};$$

$$z_2(2)_0 = 900,23 \text{ mm}; i = 2,$$

$$x_2(3)_0 = -867,86 \text{ mm}; y_2(3)_0 = -943,8 \text{ mm};$$

$$z_2(3)_0 = 1000 \text{ mm}; i = 3. \tag{5}$$

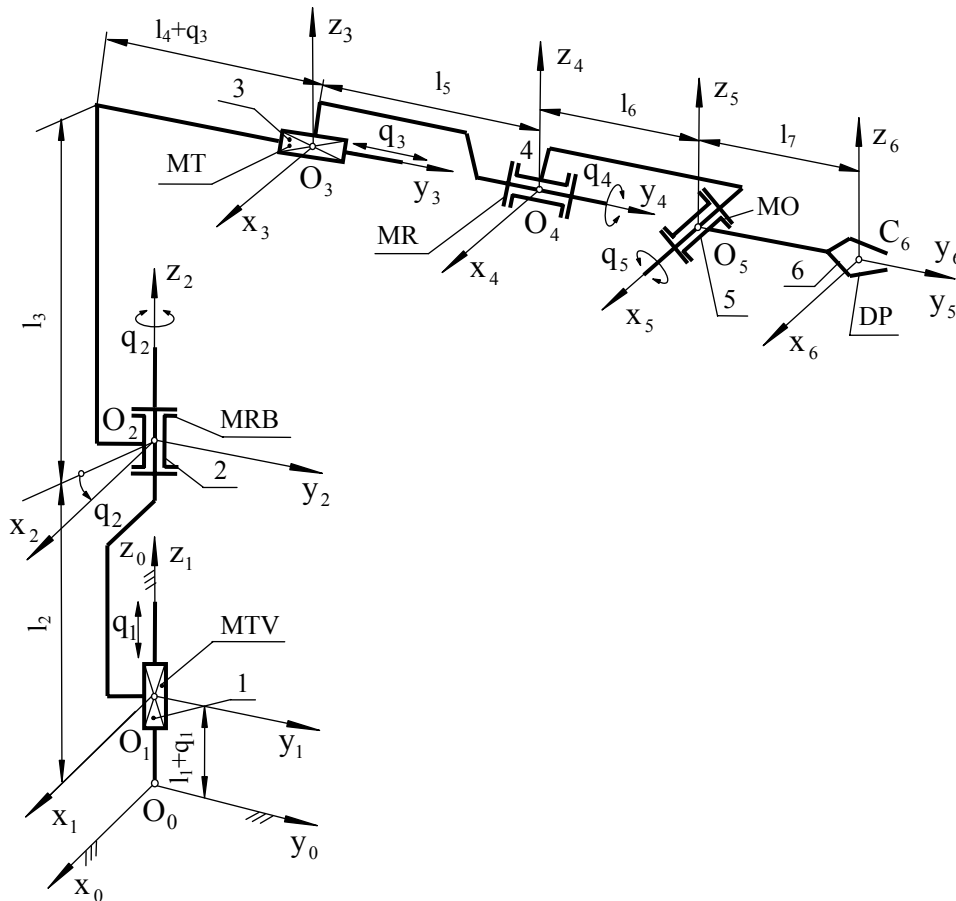


Fig.2. Kinematic Scheme of TRTTR Robot

After the lathe universal flange action in CNC1 the robot shall be withdrawn in waiting position or carry out other operations in the cell.

2. After processing the first flanges on one side, the robot picks up the gearbox of the CNC 1 given by in the previous operation, where the operation was performed by turning of roughing and finishing and positioned in the back, and later to be taken over by him and placed in the second for the other CNC side. Constructive parameters and geometrical-kinematics that characterize this phase are:

$$l_1 = 500 \text{ mm}; l_2 = 200 \text{ mm}; l_3 = 350 \text{ mm}; l_4 = 750 \text{ mm}; l_5 = 450 \text{ mm}; l_6 = 100 \text{ mm}; l_7 = 300 \text{ mm}; l_8 = -50 \text{ mm}; \varphi_2 = 135^\circ; \varphi_4 = 90^\circ; \varphi_5 = 90^\circ; q_1 = -350 \text{ mm}; q_2 = 60^\circ; q_3 = 0 \text{ mm}; q_4 = 0^\circ; q_5 = 0^\circ. \quad (6)$$

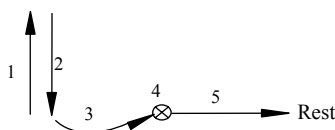


Fig.3. Processing Cycle: Second Phase

In accordance with the relations (2), (6), having defined the initial positions of characteristic points by relationship (4), of which coordinates shall be the same throughout the operating cycle of the robot, the coordinates are obtained points in final position. Those coordinates, the second phase, are the following:

$$\begin{aligned} x_2(1)_0 &= 335,10 \text{ mm}; y_2(1)_0 = -1264,17 \text{ mm}; \\ z_2(1)_0 &= 650,23 \text{ mm}; i = 1, \\ x_2(2)_0 &= 336,8 \text{ mm}; y_2(2)_0 = -1155,2 \text{ mm}; \\ z_2(2)_0 &= 550,23 \text{ mm}; i = 2, \\ x_2(3)_0 &= 333,21 \text{ mm}; y_2(3)_0 = -1258 \text{ mm}; \\ z_2(3)_0 &= 650,23 \text{ mm}; i = 3. \quad (7) \end{aligned}$$

3. The robot two of the cell of manufacture begins doing business through the acquisition of first flanges on the power strip and positions it in the third CNC.

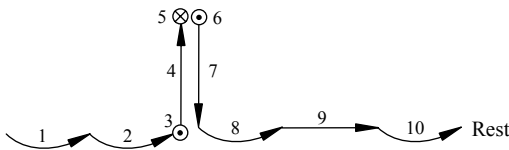


Fig.4. Processing Cycle: Third Phase

Constructive and geometric-cinematic parameters which shall be imposed on this phase and cycle schematic operation (Fig. 4.) are shown below:

$$l_1=150\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm};$$

$$l_5=450\text{mm}; l_6=100\text{mm}; l_7=300\text{mm}; l_8=-50\text{mm};$$

$$\varphi_2 = 115^\circ; \varphi_4 = 0^\circ; \varphi_5 = 90^\circ; q_1 = 350 \text{ mm}; q_2 = -70^\circ;$$

$$q_3 = 0 \text{ mm}; q_4 = 90^\circ; q_5 = 0^\circ. \quad (8)$$

For this phase, flange end position is determined by the following coordinates:

$$x_2(1)_0 = -856,71 \text{ mm}; y_2(1)_0 = 989,2 \text{ mm};$$

$$z_2(1)_0 = 1050,2 \text{ mm}; i = 1,$$

$$x_2(2)_0 = -762,8 \text{ mm}; y_2(2)_0 = 980,4 \text{ mm};$$

$$z_2(2)_0 = 950,41 \text{ mm}; i = 2,$$

$$x_2(3)_0 = -866,44 \text{ mm}; y_2(3)_0 = 993,33 \text{ mm};$$

$$z_2(3)_0 = 1050,32 \text{ mm}; i = 3. \quad (9)$$

4. The robot one of the flexible manufacturing cell returns to the power strip

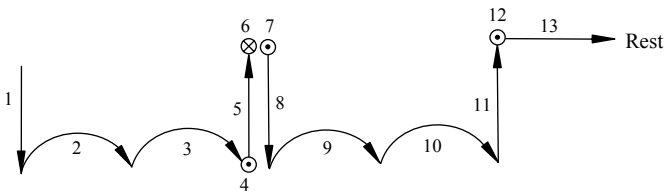


Fig.5. Processing Cycle. Fourth Phase

where takes over the second flange to power again of CNC 1. The operating cycle is shown in figure 5.

Specific numeric data this phase is:

$$l_1 = 150 \text{ mm}; l_2 = 200 \text{ mm};$$

$$l_3 = 350 \text{ mm}; l_4 = 750 \text{ mm};$$

$$l_5 = 450 \text{ mm}; l_6 = 100 \text{ mm};$$

$$l_7 = 300 \text{ mm}; l_8 = -50 \text{ mm}; \varphi_2 = 65^\circ;$$

$$\varphi_4 = 0^\circ; \varphi_5 = 90^\circ; q_1 = 350 \text{ mm}; q_2 = 70^\circ;$$

$$q_3 = 0 \text{ mm}; q_4 = 90^\circ; q_5 = 0^\circ. \quad (10)$$

The coordinates of the three points in the corresponding flange this phase in final position, are the following:

$$x_2(1)_0 = -955,90 \text{ mm}; y_2(1)_0 = -955,02 \text{ mm};$$

$$z_2(1)_0 = 1000 \text{ mm}; i = 1,$$

$$x_2(2)_0 = -964,97 \text{ mm}; y_2(2)_0 = -960,17 \text{ mm};$$

$$z_2(2)_0 = 900,23 \text{ mm}; i = 2,$$

$$x_2(3)_0 = -867,86 \text{ mm}; y_2(3)_0 = -943,8 \text{ mm};$$

$$z_2(3)_0 = 1000 \text{ mm}; i = 3. \quad (11)$$

5. Subsequently the robot second picks up first CNC flange of the (3), after it has been processed on the first front and a place in the headlands, so that it can be turned. Then this follows to be processed on the other side. The duty-cycle can be pursued in figure 6.

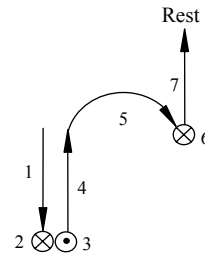


Fig.6. Processing Cycle: Fifth Phase

In this phase corresponding parameters are:

$$l_1=500\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm};$$

$$l_5=450\text{mm}; l_6=100\text{mm}; l_7=300\text{mm}; l_8=-50\text{mm};$$

$$\varphi_2=45^\circ; \varphi_4=90^\circ; \varphi_5=90^\circ; q_1=-350 \text{ mm}; q_2=-60^\circ;$$

$$q_3 = 0 \text{ mm}; q_4 = 0^\circ; q_5 = 0^\circ. \quad (12)$$

In accordance with the relationship (2), the co-ordinates flange points in final position are:

$$x_2(1)_0 = 435,10 \text{ mm}; y_2(1)_0 = 1264,17 \text{ mm};$$

$$z_2(1)_0 = 650 \text{ mm}; i=1,$$

$$x_2(2)_0 = 336,8 \text{ mm}; y_2(2)_0 = 1155,2 \text{ mm};$$

$$z_2(2)_0 = 550 \text{ mm}; i=2,$$

$$x_2(3)_0 = 430,21 \text{ mm}; y_2(3)_0 = 1258 \text{ mm};$$

$$z_2(3)_0 = 650 \text{ mm}; i=3. \quad (13)$$

6. The robot one takes the first flange of the device, after it has been turned and a place

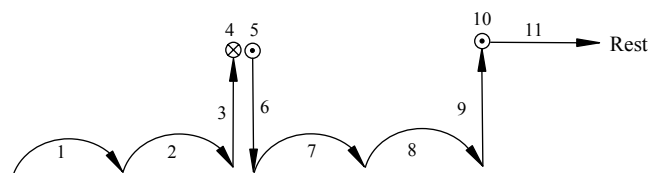


Fig.8. Processing Cycle: Seventh Phase

in the second CNC for the operation for lathing of roughing and finishing (Fig.7).

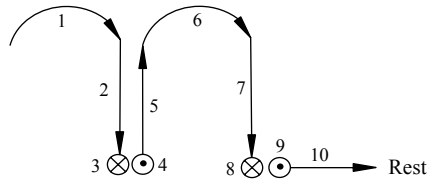


Fig.7. Processing Cycle:
Sixth Phase

This phase has the corresponding parameters:

$$\begin{aligned} l_1=150\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; \\ l_5=450\text{mm}; l_6=100\text{ mm}; l_7=300\text{ mm}; l_8=-50\text{mm}; \\ \varphi_2=195^\circ; \varphi_4=90^\circ; \varphi_5=90^\circ; q_1=350\text{ mm}; q_2=75^\circ; \\ q_3=0\text{ mm}; q_4=0^\circ; q_5=0^\circ. \end{aligned} \quad (14)$$

Final positions of flange points shall be determined in accordance with the relationship (2), using the following coordinates:

$$\begin{aligned} x_2(1)_0 &= 1299,15\text{ mm}; \\ y_2(1)_0 &= 0,15\text{ mm}; z_2(1)_0 = 1050,01\text{ mm}; i=1, \\ x_2(2)_0 &= 1254,34\text{ mm}; y_2(2)_0 = 0,29\text{ mm}; \\ z_2(2)_0 &= 860,01\text{ mm}; i=2, \\ x_2(3)_0 &= 1300\text{ mm}; y_2(3)_0 = 0,15\text{ mm}; \\ z_2(2)_0 &= 1050,01\text{ mm}; i=3. \end{aligned} \quad (15)$$

7. The robot two is back toward the power strip where take the second flange, on which a seated in universal third of the CNC processing, following flange on the side with a smaller diameter. The work cycle is given in the figure 8. Specific numeric data this phase is:

$$\begin{aligned} l_1=150\text{ mm}; l_2=200\text{ mm}; l_3=350\text{ mm}; \\ l_4=750\text{ mm}; l_5=450\text{ mm}; l_6=100\text{ mm}; \\ l_7=300\text{ mm}; l_8=-50\text{ mm}; \varphi_2=115^\circ; \\ \varphi_4=0^\circ; \varphi_5=90^\circ; q_1=350\text{ mm}; q_2=-70^\circ; q_3=0 \\ \text{mm}; q_4=90^\circ; q_5=0^\circ. \end{aligned} \quad (16)$$

The coordinates of the three points corresponding to this phase in the final position, are the following:

$$\begin{aligned} x_2(1)_0 &= -856,71\text{ mm}; y_2(1)_0 = 989,2\text{ mm}; \\ z_2(1)_0 &= 1050,2\text{ mm}; i=1, \\ x_2(2)_0 &= -762,8\text{ mm}; y_2(2)_0 = 980,4\text{ mm}; \\ z_2(2)_0 &= 950,41\text{ mm}; i=2, \\ x_2(3)_0 &= -866,44\text{ mm}; y_2(3)_0 = 993,33\text{ mm}; \\ z_2(3)_0 &= 1050,32\text{ mm}; i=3. \end{aligned} \quad (17)$$

8. First robot takes the second flange of the first CNC and a place in the device for carrying out the operation of headland, in accordance with the operating cycle shown in figure 9.

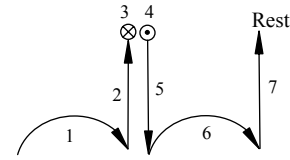


Fig.9. Processing Cycle:
Eighth Phase

Numerical data corresponding to this phase are:

$$\begin{aligned} l_1=500\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; \\ l_5=450\text{mm}; l_6=100\text{mm}; l_7=300\text{mm}; l_8=-50\text{mm}; \\ \varphi_2=135^\circ; \varphi_4=90^\circ; \varphi_5=90^\circ; q_1=-350\text{ mm}; \\ q_2=60^\circ; q_3=0\text{ mm}; q_4=0^\circ; q_5=0^\circ. \end{aligned} \quad (18)$$

Data resulting from calculations with the program MatLab 7.1 are:

$$\begin{aligned} x_2(1)_0 &= 335,10\text{ mm}; y_2(1)_0 = -1264,17\text{ mm}; \\ z_2(1)_0 &= 650,23\text{ mm}; i=1, \\ x_2(2)_0 &= 336,8\text{ mm}; y_2(2)_0 = -1155,2\text{ mm}; \\ z_2(2)_0 &= 550,23\text{ mm}; i=2, \\ x_2(3)_0 &= 333,21\text{ mm}; y_2(3)_0 = -1258\text{ mm}; \\ z_2(3)_0 &= 650,23\text{ mm}; i=3, \end{aligned} \quad (19)$$

which positions flange at the end of this cycle of the robot.

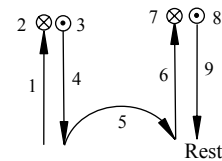


Fig.10. Processing Cycle:
Ninth Phase

9. The robot two take first flange of the headlands and a seated in CNC 4 (Fig.10). The built cinematic parameters of this cycle are:

$$\begin{aligned} l_1=150\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; l_5 \\ =450\text{mm}; l_6=100\text{ mm}; l_7=300\text{ mm}; l_8=-50 \\ \text{mm}; \varphi_2=345^\circ; \varphi_4=90^\circ; \varphi_5=90^\circ; q_1=350 \\ \text{mm}; q_2=-75^\circ; q_3=0\text{ mm}; q_4=0^\circ; q_5=0^\circ. \end{aligned} \quad (20)$$

Data resulting from calculations carried out with the program MatLab 7.1 (MAR93), positioning flange after this cycle, are the following:

$$\begin{aligned}
 x_2(1)_0 &= 1299,48 \text{ mm;} \\
 y_2(1)_0 &= 0,07 \text{ mm;} \quad z_2(1)_0 = 1050 \text{ mm;} \quad i=1, \\
 x_2(2)_0 &= 1278 \text{ mm;} \quad y_2(2)_0 = 0,01 \text{ mm;} \\
 z_2(2)_0 &= 963,7 \text{ mm;} \quad i=2, \\
 x_2(3)_0 &= 1299,66 \text{ mm;} \quad y_2(3)_0 = 0,07 \text{ mm;} \\
 z_2(3)_0 &= 1050 \text{ mm;} \quad i=3.
 \end{aligned}
 \tag{21}$$

10. First flange is taken from universal CNC 2 by the robot one and is placed on the table fixed machine drill, to be executed attaching holes of flange. The processing cycle is given in the figure 11.

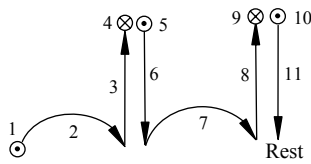


Fig.11.Processing Cycle Tenth Phase

For this phase, the building and kinematics parameters are:

$$\begin{aligned}
 l_1=500\text{mm;} \quad l_2=200\text{mm;} \quad l_3=350\text{mm;} \quad l_4=750\text{mm;} \\
 l_5=450\text{mm;} \quad l_6=100\text{mm;} \quad l_7=300\text{mm;} \quad l_8=-50\text{mm;} \\
 \varphi_2=270^\circ; \quad \varphi_4=90^\circ; \varphi_5=90^\circ; \quad q_1=-350\text{mm;} \quad q_2=90^\circ; \\
 q_3=0\text{mm;} \quad q_4=90^\circ; \quad q_5=0^\circ
 \end{aligned}
 \tag{22}$$

Data resulting from calculations, define flange position at the end of this cycle. Their values are:

$$\begin{aligned}
 x_2(1)_0 &= 0,03 \text{ mm;} \quad y_2(1)_0 = 1299,01 \text{ mm;} \\
 z_2(1)_0 &= 700,01 \text{ mm;} \quad i=1, \\
 x_2(2)_0 &= 0,05 \text{ mm;} \quad y_2(2)_0 = 1284,55 \text{ mm;} \\
 z_2(2)_0 &= 650 \text{ mm;} \quad i=2, \\
 x_2(3)_0 &= 0,03 \text{ mm;} \quad y_2(3)_0 = 1298,48 \text{ mm;} \\
 z_2(3)_0 &= 700,01 \text{ mm;} \quad i=3.
 \end{aligned}
 \tag{23}$$

11. The second flange is taken by the robot one of the headlands and placed in CNC universal 2 (Fig.12).

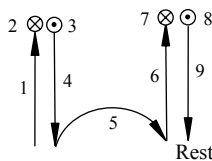


Fig.12. Processing Cycle Eleventh Phase

The cinematic and built parameters set in this phase are:

$$\begin{aligned}
 l_1=150\text{mm;} \quad l_2=200\text{mm;} \quad l_3=350\text{mm;} \quad l_4=750\text{mm;} \\
 l_5=450\text{mm;} \quad l_6=100\text{mm;} \quad l_7=300\text{mm;} \quad l_8=-50\text{mm;} \\
 \varphi_2=195^\circ; \quad \varphi_4=90^\circ; \quad \varphi_5=90^\circ; \quad q_1=350\text{mm;} \\
 q_2=75^\circ; \quad q_3=0\text{mm;} \quad q_4=0^\circ; \quad q_5=0^\circ.
 \end{aligned}
 \tag{24}$$

In accordance with the relationship (2) and the relation (24), the co-ordinates of points final position flange are as follows:

$$\begin{aligned}
 x_2(1)_0 &= 1299,15 \text{ mm;} \quad y_2(1)_0 = 0,15 \text{ mm;} \\
 z_2(1)_0 &= 1050,01 \text{ mm;} \quad i=1, \\
 x_2(2)_0 &= 1254,34 \text{ mm;} \quad y_2(2)_0 = 0,29 \text{ mm;} \\
 z_2(2)_0 &= 860,01 \text{ mm;} \quad i=2, \\
 x_2(3)_0 &= 1300 \text{ mm;} \quad y_2(3)_0 = 0,15 \text{ mm;} \\
 z_2(2)_0 &= 1050,01 \text{ mm;} \quad i=3.
 \end{aligned}
 \tag{25}$$

12. The robot two picks up the two flange of universal third CNC, a place in the back, in order to be turned over, and then sit down in CNC processing faces(4) for large diameter.

Kinematic parameters are imposed schematic this start-up phase and cycle of operation (Fig.13) are shown below:

$$\begin{aligned}
 l_1=500\text{mm;} \quad l_2=200\text{mm;} \quad l_3=350\text{mm;} \quad l_4=750\text{mm;} \\
 l_5=450\text{mm;} \quad l_6=100\text{mm;} \quad l_7=300\text{mm;} \quad l_8=-50\text{mm;} \\
 \varphi_2=45^\circ; \quad \varphi_4=90^\circ; \quad \varphi_5=90^\circ; \quad q_1=-350\text{mm;} \\
 q_2=-60^\circ; \quad q_3=0\text{mm;} \quad q_4=0^\circ; \quad q_5=0^\circ.
 \end{aligned}
 \tag{26}$$

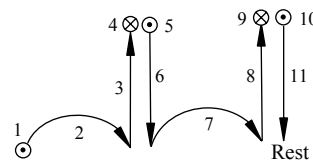


Fig.13. Processing Cycle: Twelfth Phase

Final position of the flange corresponding to this phase is defined by the coordinates:

$$\begin{aligned}
 x_2(1)_0 &= 435,10 \text{ mm;} \quad y_2(1)_0 = 1264,17 \text{ mm;} \\
 z_2(1)_0 &= 650 \text{ mm;} \quad i=1, \\
 x_2(2)_0 &= 336,8 \text{ mm;} \quad y_2(2)_0 = 1155,2 \text{ mm;} \\
 z_2(2)_0 &= 550 \text{ mm;} \quad i=2, \\
 x_2(3)_0 &= 430,21 \text{ mm;} \quad y_2(3)_0 = 1258 \text{ mm;} \\
 z_2(2)_0 &= 650 \text{ mm;} \quad i=3.
 \end{aligned}
 \tag{27}$$

13. After they have been executed attaching holes, the robot one takes over the flange of the drilling machine, rotates and gives the band flange on the exhaust.

Kinematic parameters are imposed schematic this start-up phase and cycle of operation (Fig.14) are shown below:

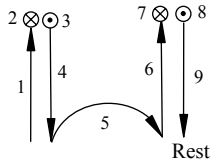


Fig.14. Processing Cycle:
Thirteenth Phase

$l_1=150\text{mm}$; $l_2=200\text{mm}$; $l_3=350\text{mm}$; $l_4=750\text{mm}$;
 $l_5 = 450 \text{ mm}$; $l_6 = 100 \text{ mm}$; $l_7 = 300 \text{ mm}$; $l_8 = -50 \text{ mm}$;
 $\varphi_2 = 0^\circ$; $\varphi_4 = 0^\circ$; $\varphi_5 = 90^\circ$; $q_1 = -200 \text{ mm}$;
 $q_2 = -20^\circ$; $q_3 = 0 \text{ mm}$; $q_4 = 0^\circ$; $q_5 = 0^\circ$ (28)

Final Position of the flange corresponding to this phase is defined by the following coordinates:

$$\begin{aligned} x_2(1)_0 &= 388,41 \text{ mm}; \\ y_2(1)_0 &= 1301,48 \text{ mm}; z_2(1)_0 = 500 \text{ mm}; \quad i=1, \\ x_2(2)_0 &= 378,79\text{mm}; \quad y_2(2)_0 = 1299,37 \text{ mm}; \\ z_2(2)_0 &= 498,79 \text{ mm}; \quad i=2, \\ x_2(3)_0 &= 388,41\text{mm}; \quad y_2(3)_0 = 1302,01 \text{ mm}; \\ z_2(3)_0 &= 500 \text{ mm}; \quad i=3. \end{aligned} \quad (29)$$

14. The second robot making the headlines universal flange of CNC-4, after it has been carried out the operation to lathing roughing and finishing and put it on the machine table drill (Fig.15). Numeric input data corresponding to this cycle are:

$l_1=500\text{mm}$; $l_2=200\text{mm}$; $l_3=350\text{mm}$; $l_4=750\text{mm}$;
 $l_5 = 450 \text{ mm}$; $l_6 = 100 \text{ mm}$; $l_7 = 300 \text{ mm}$; $l_8 = -50 \text{ mm}$;
 $\varphi_2 = 270^\circ$; $\varphi_4 = 90^\circ$; $\varphi_5 = 90^\circ$; $q_1 = -350 \text{ mm}$;
 $q_2 = -90^\circ$; $q_3 = 0 \text{ mm}$; $q_4 = 90^\circ$; $q_5 = 0^\circ$.(30)

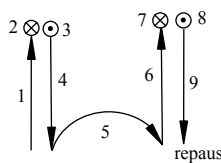


Fig.15. Processing Cycle:
Fourteenth Phase

Final position of the flange corresponding

to this phase is defined by the following coordinates:

$$\begin{aligned} x_2(1)_0 &= 0,03 \text{ mm}; \\ y_2(1)_0 &= -1299,01 \text{ mm}; z_2(1)_0 = 700 \text{ mm}; \quad i=1, \\ x_2(2)_0 &= 0,05 \text{ mm}; \\ y_2(2)_0 &= -1284,55 \text{ mm}; z_2(2)_0 = 650 \text{ mm}; \quad i=2, \\ x_2(3)_0 &= 0,03 \text{ mm}; \quad y_2(3)_0 = -1298,48 \text{ mm}; \\ z_2(3)_0 &= 700 \text{ mm}; \quad i=3. \end{aligned} \quad (31)$$

15. The robot two takes over the second flange of the headlands, after it is turned over, according to implement CNC-4 for processing on the face each other (Fig.16).

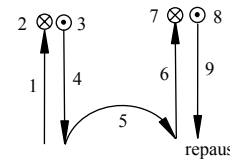


Fig.16. Processing Cycle:
Fifteenth Phase

Constructive and geometric-cinematic parameters ever seen in this phase are:

$l_1=150\text{mm}$; $l_2=200\text{mm}$; $l_3=350\text{mm}$; $l_4=750\text{mm}$;
 $l_5=450 \text{ mm}$; $l_6=100\text{mm}$; $l_7=300\text{mm}$; $l_8=-50\text{mm}$;
 $\varphi_2 = 345^\circ$; $\varphi_4 = 90^\circ$; $\varphi_5 = 90^\circ$; $q_1 = 350 \text{ mm}$; $q_2 = -75^\circ$;
 $q_3 = 0 \text{ mm}$; $q_4 = 0^\circ$; $q_5 = 0^\circ$. (32)

In accordance with the relationship (2) and the relation (32), and final position point coordinates of the flange are as follows:

$$\begin{aligned} x_2(1)_0 &= 1299,48 \text{ mm}; \\ y_2(1)_0 &= 0,07 \text{ mm}; z_2(1)_0 = 1050 \text{ mm}; \quad i=1, \\ x_2(2)_0 &= 1278 \text{ mm}; \quad y_2(2)_0 = 0,01 \text{ mm}; \\ z_2(2)_0 &= 963,7 \text{ mm}; \quad i=2, \\ x_2(3)_0 &= 1299,66 \text{ mm}; \quad y_2(3)_0 = 0,07 \text{ mm}; \\ z_2(3)_0 &= 1050 \text{ mm}; \quad i=3. \end{aligned} \quad (33)$$

16. The robot two, after putting the second flange in CNC 4, takes over the flange on the machine table drilling, and put it on a strip of exhaust.

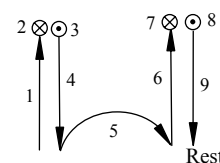


Fig.17. Processing Cycle:
Sixteenth Phase

The kinematic and constructive parameters are imposed sixteenth phase as cycle of operation diagram (Fig.17) is shown below:

$$l_1=150\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; l_5 = 450 \text{ mm}; l_6 = 100 \text{ mm}; l_7 = 300 \text{ mm}; l_8 = -50 \text{ mm}; \varphi_2 = 180^\circ; \varphi_4 = 0^\circ; \varphi_5 = 90^\circ; q_1 = -200 \text{ mm}; q_2 = 20^\circ; q_3 = 0 \text{ mm}; q_4 = 0^\circ; q_5 = 0^\circ. \quad (34)$$

Final position of the flange corresponding to this phase is defined by the following coordinates:

$$\begin{aligned} x_2(1)_0 &= 388,41 \text{ mm}; \\ y_2(1)_0 &= 1301,48 \text{ mm}; z_2(1)_0 = 500 \text{ mm}; \quad i=1, \\ x_2(2)_0 &= 378,79\text{mm}; y_2(2)_0 = 1299,37 \text{ mm}; \\ z_2(2)_0 &= 498,79 \text{ mm}; \quad i=2, \\ x_2(3)_0 &= 388,41\text{mm}; y_2(3)_0 = 1302,01 \text{ mm}; \\ z_2(3)_0 &= 500 \text{ mm}; \quad i=3. \end{aligned} \quad (35)$$

17. The robot one takes the second flange of CNC 2 after it has been processed and a positioned on the machine table. This phase has the following parameter:

$$l_1=500\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; l_5 = 450 \text{ mm}; l_6 = 100 \text{ mm}; l_7 = 300 \text{ mm}; l_8 = -50 \text{ mm}; \varphi_2 = 270^\circ; \varphi_4 = 90^\circ; \varphi_5 = 90^\circ; q_1 = -350 \text{ mm}; q_2 = 90^\circ; q_3 = 0 \text{ mm}; q_4 = 90^\circ; q_5 = 0^\circ. \quad (36)$$

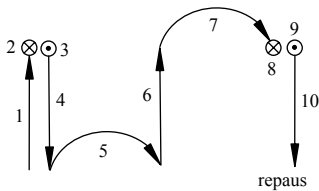


Fig.18. Processing Cycle: Seventeenth Phase

Final Position of flange corresponding at seventeenth phase is defined by the coordinates of the three points:

$$\begin{aligned} x_2(1)_0 &= 0,03 \text{ mm}; y_2(1)_0 = 1299,01 \text{ mm}; \\ z_2(1)_0 &= 700,01 \text{ mm}; \quad i=1, \\ x_2(2)_0 &= 0,05 \text{ mm}; y_2(2)_0 = 1284,55 \text{ mm}; \\ z_2(2)_0 &= 650 \text{ mm}; \quad i=2, \\ x_2(3)_0 &= 0,03 \text{ mm}; y_2(3)_0 = 1298,48 \text{ mm}; \\ z_2(3)_0 &= 700,01 \text{ mm}; \quad i=3. \end{aligned} \quad (37)$$

18. The first robot picks up the second flange on the machine table drill and put it on a

strip of exhaust.

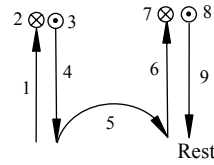


Fig.19. Processing Cycle: Eighteenth Phase

Numeric data to be taken in this working cycle (Fig.19), are as shown below:

$$l_1=150\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; l_5=450\text{mm}; l_6 = 100 \text{ mm}; l_7 = 300 \text{ mm}; l_8 = -50 \text{ mm}; \varphi_2 = 0^\circ; \varphi_4 = 0^\circ; \varphi_5 = 90^\circ; q_1 = -200 \text{ mm}; q_2 = -20^\circ; q_3 = 0 \text{ mm}; q_4 = 0^\circ; q_5 = 0^\circ. \quad (38)$$

Final position of the flange is expressed by means of the following co-ordinates of each of the three points:

$$\begin{aligned} x_2(1)_0 &= 388,41 \text{ mm}; \\ y_2(1)_0 &= 1301,48 \text{ mm}; z_2(1)_0 = 500 \text{ mm}; \quad i=1, \\ x_2(2)_0 &= 378,79\text{mm}; y_2(2)_0 = 1299,37 \text{ mm}; \\ z_2(2)_0 &= 498,79 \text{ mm}; \quad i=2, \\ x_2(3)_0 &= 388,41\text{mm}; y_2(3)_0 = 1302,01 \text{ mm}; \\ z_2(3)_0 &= 500 \text{ mm}; \quad i=3. \end{aligned} \quad (39)$$

19. The second robot takes over the second flange of CNC 4 and put it on the machine table drill for making the holes. Cycle of the robot is shown in figure 20.

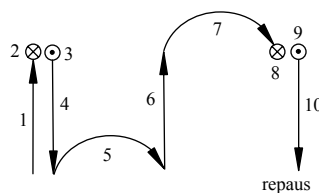


Fig.20. Processing Cycle: Nineteenth Phase

The parameters which characterized by the working cycle are:

$$l_1=500\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; l_5=450 \text{ mm}; l_6=100\text{mm}; l_7=300\text{mm}; l_8=-50\text{mm}; \varphi_2 = 270^\circ; \varphi_4 = 90^\circ; \varphi_5 = 90^\circ; q_1 = -350 \text{ mm}; q_2 = -90^\circ; q_3 = 0 \text{ mm}; q_4 = 90^\circ; q_5 = 0^\circ. \quad (40)$$

Final Position of corresponding flange phase XIX-a, is defined by the coordinates:

$$\begin{aligned} x_2(1)_0 &= 0,03 \text{ mm}; y_2(1)_0 = -1299,01 \text{ mm}; \\ z_2(1)_0 &= 700 \text{ mm}; \quad i=1, \end{aligned}$$

$$\begin{aligned}
 x_2(2)_0 &= 0,05 \text{ mm}; y_2(2)_0 = -1284,55 \text{ mm}; \\
 z_2(2)_0 &= 650 \text{ mm}; i=2, \\
 x_2(3)_0 &= 0,03 \text{ mm}; y_2(3)_0 = -1298,48 \text{ mm}; \\
 z_2(3)_0 &= 700 \text{ mm}; i=3.
 \end{aligned}
 \quad (41)$$

20. The second robot catches the second flange from the machine table drill and put it on a strip of exhaust. In the figure 21 is presented the operating cycle of the food processor. The kinematic and constructive parameters that occur in this phase are listed below:

$$\begin{aligned}
 l_1=150\text{mm}; l_2=200\text{mm}; l_3=350\text{mm}; l_4=750\text{mm}; \\
 l_5=450 \text{ mm}; l_6 = 100 \text{ mm}; l_7 = 300 \text{ mm}; l_8 = - 50 \\
 \text{mm}; \varphi_2 = 180^\circ; \varphi_4 = 0^\circ; \varphi_5 = 90^\circ; q_1 = - 200 \\
 \text{mm}; q_2 = 20^\circ; q_3 = 0 \text{ mm}; q_4 = 0^\circ; q_5 = 0^\circ.
 \end{aligned}
 \quad (42)$$

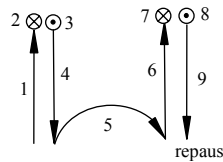


Fig.21. Processing Cycle:
Twentieth Phase

The coordinates flange points in final position are as follows, in accordance with [Man01]:

$$\begin{aligned}
 x_2(1)_0 &= 388,41 \text{ mm}; \\
 y_2(1)_0 &= 1301,48 \text{ mm}; z_2(1)_0 = 500 \text{ mm}; i=1, \\
 x_2(2)_0 &= 378,79\text{mm}; y_2(2)_0 = 1299,37 \text{ mm}; \\
 z_2(2)_0 &= 498,79 \text{ mm}; i=2, \\
 x_2(3)_0 &= 388,41\text{mm}; y_2(3)_0 = 1302,01 \text{ mm}; \\
 z_2(3)_0 &= 500 \text{ mm}; i=3.
 \end{aligned}
 \quad (43)$$

As a result of the application of the calculation algorithm presented have resulted in final positions of flange for each of the 20 phases of the working cycle of the two robots.

3. CONCLUSIONS

1. Setting up manufacturing cells is done in different ways. The novelty of this work consists in the use of the theory of finite displacements for the determination of machines tools, devices, turning the power strip

and evacuation compared to robots positions within the cell fabrication.

2. Considering that the starting position of the flange determined by the coordinates of the three points as distinct from its non-collinearity, there are also rototranslation x-axis movement parameters and parameters of robot kinematics geometric required travel flange, one can determine the final position of the flange, established by the same three points of coordinates flange. The final position of the flange thus determined defines the position of the same three points of flange. The final position of the flange thus determined defines the position within the cell fabrication machinery and auxiliary devices serving the cell.

3. To set up the cell fabrication of flange it is necessary to establish the manufacturing technology, detailed execution phases. The results are in 20 stages of the cycle of the two robots. For each of these phases have been determined final positions in respective processing flange, meaning lucrative units in the positions of the cell fabrication. In cell fabrication so configured, the axis of symmetry of the flange must be identical in sequence with the axes of symmetry of universal machines tools, namely with the axis of symmetry of the back (Fig. 22).

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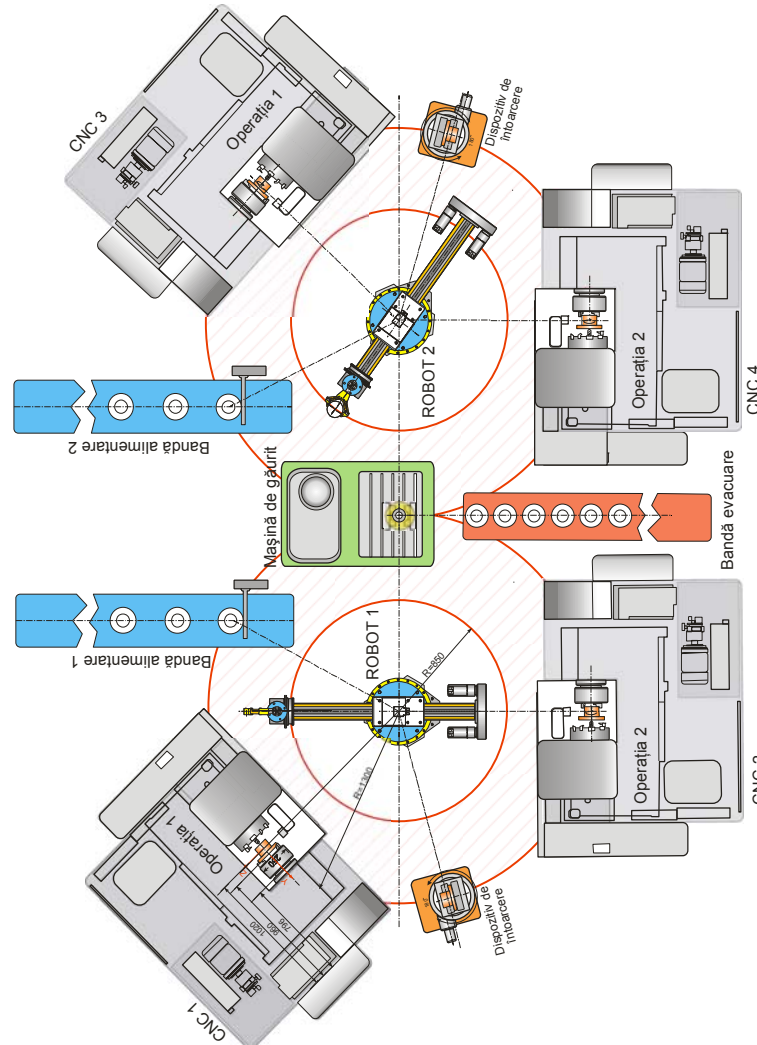


Fig. 22. Flexible Cell for the Large Flanges Processing

Celă flexibilă pentru prelucrarea flanșelor mari

Rezumat: Lucrarea prezintă o celulă flexibilă de fabricație, cu centrele de prelucrare situate în aceeași parte a robotului pentru prelucrarea flanșelor mari. Cazul prezentat este cu centrele de prelucrare ale aceleiași operații situate pe partea stângă a robotului. Se prezintă, se analizează și se dimensionează parametrii constructivi și geometrico-cinematici pe faze. Cazul prezentat este unic în literatura de specialitate, pentru acest tip de centre de prelucrare.

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