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SYNTHESIS MECHANISM TO GUIDE THE AXIS WHICH SUPPORTS A SCIO MOLECULAR SPECTROMETER

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ABSTRACT: The paper presents a dimensioning method for a five-bar mechanism of a robot that positions a molecular spectrometer SCIO in a determined work space; method is used for parametric design of the robot by using Visual Basic programming environment of MS Office Excel application; EXCEL obtained table is taken for parametric design of the five-bar mechanism in CATIA, for a required workspace. This mechanism supports a molecular spectrometer SCIO in order to measure the content of antioxidants in vegetables and fruits. In order to verify the correctness of dimensioning, the mechanism was modeled in Catia V5 and it was simulated the kinematics movement results of the standard sizes.
Keywords: Five-bar mecanism,Catia, modelling, simulation

1.INTRODUCTION

The SCARA is acronym for Selective Compliant Assembly Robot Arm or Selective Compliance Articulated Robot Arm [2]. It was first developed in Yamanashi University of Kofu, Japan by Hiroshi Makino. Today this configuration is adopted by companies all over the world like AIBO, COBRA, EPSON, KUKA, STÄUBLI, YAMAHA, for industrial tasks and in the medical field [2].
This type of robot has been first used as an industrial robot for pick and place tasks, assembly tasks, painting etc. after, entering into the medical field as well. As the name describes, the main function is to simulate an articulated arm, having in its structure an open, articulated kinematic chain, placed in the horizontal plane of the robot [2]. The described mechanism is the serial SCARA Robot.
Further in this paper is presented a dimensioning method for a five-bar mechanism where the distance between the joints is zero, they are called Double SCARA Robot.

2. MECHANICAL SYNTHESIS OF FIVE-BAR MECHANISM

The synthesis of five-bar mechanism for guiding the axis which supports a molecular spectrometer SCIO. Dimensioning and kinematics computations take place in plan working space. We consider a prism as working space. Prism bases is a polygon. Usually, these points are defined in Cartesian coordinates[7]. The contour equation (1) for point C shown in Figure 1.

$$\overline{AC} = \overline{AB} + \overline{BC} \quad (1)$$

In reference system associated to five-bar mechanism, we considered the polar radius:

$$\rho = AC \quad (2)$$

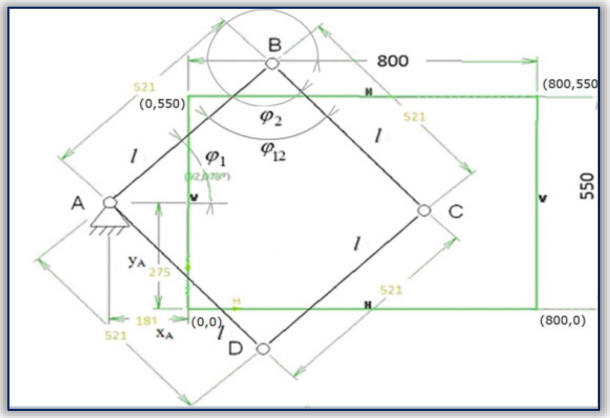

Figure 1: Five-bar mechanism

The lenght of elements are equal (3):

$$l = AB = BC = CD = DA \tag{3}$$

The vectorial equation (1) has been projected on pentalater base and we get the scalar projection in equation (4).

$$\rho = l \cdot \cos\varphi_1 + l \cdot \cos\varphi_2 \tag{4}$$

Having:

$$\varphi_1 = \frac{\pi - \varphi_{12}}{2} = \frac{\pi}{2} - \frac{\varphi_{12}}{2} \qquad \varphi_2 = 2\cdot\pi - \frac{\pi - \varphi_{12}}{2} = -\frac{\pi}{2} + \frac{\varphi_{12}}{2} \qquad (5)\text{-}(6)$$

Relations (5) and (6) were substituted in equation (4) getting relation (7):

$$\rho = l\cdot\cos\left(\frac{\pi}{2} - \frac{\varphi_{12}}{2}\right) + l\cdot\cos\left(\frac{\pi}{2} + \frac{\varphi_{12}}{2}\right) \qquad \rho = l\cdot\sin\left(\frac{\varphi_{12}}{2}\right) + l\cdot\cos\left(\frac{\varphi_{12}}{2}\right) \qquad \rho = 2\cdot l\cdot\sin\left(\frac{\varphi_{12}}{2}\right) \tag{7}$$

For the case of the minimum angle between the elements 1 and 2: $\varphi_{12} = \varphi_m$. This case corresponds to the minimum value of the polar radius:

$$\rho_m = 2\cdot l\cdot\sin\left(\frac{\varphi_m}{2}\right) \tag{8}$$

The maximum angle between elements 1 and 2 is $\varphi_{12} = \varphi_M$ corresponds to maximum value for polar radius:

$$\rho_M = 2\cdot l\cdot\sin\left(\frac{\varphi_M}{2}\right) \tag{9}$$

The difference between the minimum and maximum polar radius point C must be greater than the distance d_C defined in (10), follows that the length of (linked five-bar mechanism) elements must meet the condition (11).

$$\begin{aligned} &d_C \le \rho_M - \rho_m \\ &d_C \le 2\cdot l\cdot\left(\sin\left(\frac{\varphi_M}{2}\right) - \sin\left(\frac{\varphi_m}{2}\right)\right). \end{aligned} \tag{10}$$

$$l \ge \frac{d_C}{2\cdot\left(\sin\left(\frac{\varphi_M}{2}\right) - \sin\left(\frac{\varphi_m}{2}\right)\right)}. \tag{11}$$

It may further determine, the joint abscissa A, on the polar axis of the base prismatic workspace, from the condition that the eadge with the minimum value of abscissa has to be in the the achievable sided, so the eadge pointing A of radius equal to the radius polar minimum, has to be tangent to the right of abscissa defined minimum base workspace peaks, x_{Vmin}:

$$x_A = x_{V\min} - 2\cdot l\cdot\sin\left(\frac{\varphi_m}{2}\right) \tag{12}$$

As previously it was adopted, based on the prismatic workspace, polar axis has to be parallel to the abscissa, and the ordinate axis has to be the medium ordered vertices corresponding to the prismatic base:

$$y_A = \frac{y_{V\max} + y_{V\min}}{2} \tag{13}$$

Due to the fact that elements 1 and 4 are articulated based on the same point, and lengths of mobile (five-bar mechanism) sided elements (elements 1,2,3 and 4) Relationships Between these result GMT on the polar angles of the elements axis of the base workspace:

$$\begin{cases} \varphi_1 = \varphi_3; \\ \varphi_2 + \pi = \varphi_4; \end{cases} \tag{14}$$

For determination of minimum and maximum angles for elements 1 and 4 of five-bar mechanism to the polar axis of workspace base it is required that the point C from the five-bar mechanism, has to coincide with any of the N vertices of the workspace base:

$$x_{Vi}, y_{Vi} \quad i = \overline{1,N}$$

Resulting N vectorial equations as follows:

$$\overline{OA} + \overline{AB} = \overline{OV_i} + \overline{CB} \quad i = \overline{1,N} \tag{15}$$

These vectorial quations have corresponding N linear system equations as follow:

$$\begin{cases} 1 \cdot \cos\varphi_{1i} - 1 \cdot \cos\varphi_{2i} + x_A - x_{Vi} = 0 \\ 1 \cdot \sin\varphi_{1i} - 1 \cdot \sin\varphi_{2i} + y_A - y_{Vi} = 0 \end{cases} \qquad (16)$$

$$i = \overline{1,N}$$

From these equations results N values for φ_1 anglesand also N values for angles $\varphi_4 = \varphi_2 + \pi$.
We noted:

$$k = x_{Vi} - x_A,\ h = y_{Vi} - y_A,\ A = 2 \cdot k \cdot 1,\ B = 2 \cdot h \cdot 1,\ C = k^2 + h^2 \qquad (17)\text{-}(21)$$

Angle φ_1 can be calculated from the relationshiop as folow:

$$\sin\varphi_1 = \frac{B \cdot C + A \cdot \sqrt{A^2 + B^2 - C^2}}{A^2 + B^2} \qquad \cos\varphi_1 = \frac{A \cdot C - B \cdot \sqrt{A^2 + B^2 - C^2}}{A^2 + B^2} \qquad \varphi_1 = \mathrm{arctg}\frac{\sin\varphi_1}{\cos\varphi_1} \qquad (22)\text{-}(24)$$

$$\sin\varphi_2 = \frac{1 \cdot \sin\varphi_1 - h}{1} \qquad \cos\varphi_2 = \frac{1 \cdot \cos\varphi_1 - k}{1} \qquad \varphi_2 = \mathrm{arctg}\frac{\sin\varphi_2}{\cos\varphi_2} \qquad (25)\text{-}(27)$$

Resulting N values for the angles φ_1. From those angles were identified the extreme values φ_{1Max} and φ_{1min}, also N values for the angles $\varphi_4 = \varphi_2 + \pi$, of which are identified extreme values, φ_{4Max} and φ_{4min}. To facilitate the synthesis of five-bar mechanism, according to the various workspaces, we developed a program in Visual Basic for Excel.

EXCEL user interface, results after appropriate data processing equipment are presented in Table 1.

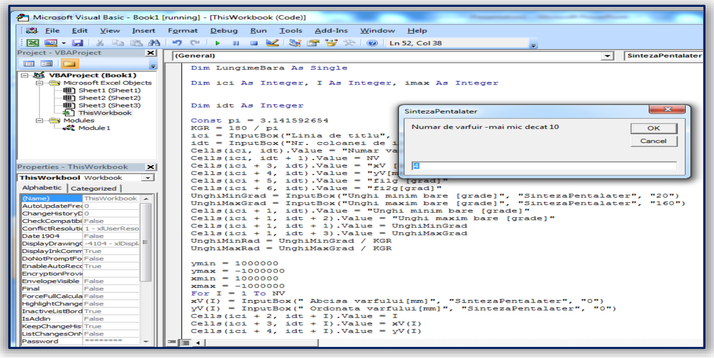

Figure 2: Calculation program interface Visual Basic (Excel) – introducing the end effector position values

Table 1: Results of computing process (are represented in red colour).

Element lenght [mm]	fi1min[grade]	fi1max[grade]	fi2min[grade]	fi2max[grade]	xA[mm]	yA[mm]
521	-3.550620221	128.2295793	51.77038322	183.5506568	-181	275
Number of vertices	4					
Minimum angle bars [grade]	20	Maximum angle bars [grade]	160			
	1	2	3	4		
xV [mm]	0	800	0	800		
yV[mm]	550	550	0	0		
fi1g[grad]	128.2295793	27.76853294	14.93398892	-3.550620221		
fi2g[grad]	165.0659736	183.5506568	51.77038322	152.2314296		

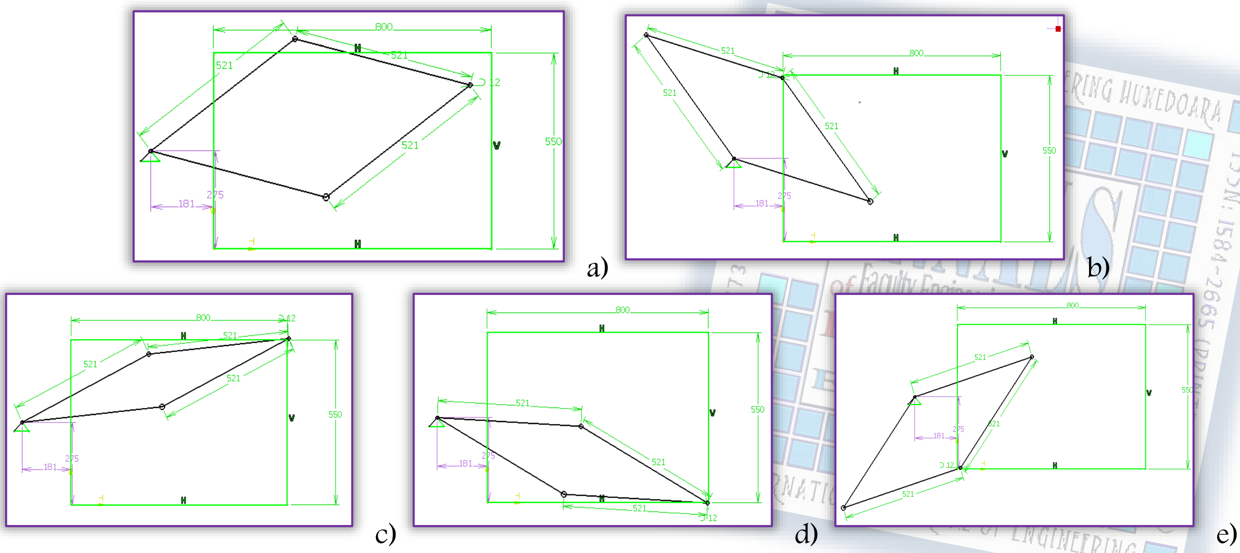

Figure 4: Intermediary positions for the five-bar mechanism (a,b,c,d,e).

In Figure 4 (a, b, c, d, e) it is shown a five-bar mechanism in CATIA V5 Sketcher, used to verify the mechanism synthesis. It is checked if the angles between the bars are too small so as do not appear rotation couplings lock due to friction by using polygon forces in the technological point of application. Segments directions representing the vectors were consistent with the mechanism analyzed position, animated extreme positions in the four extreme points of poligonal workspace.

3.CONCLUSION

It was developed a VBA for Excel program that can be used in parameterized robot design for five-bar mechanism in various CAD-CAM-CAE solutions, running on Widows operating system. Input data are the coordinates of the polygon vertices in plane workspace. Output data, that can be taken by CAD-CAM-CAE solution considered (Inventor, Catia etc.) are five-bar mechanism elements lengths and maximum and minimum values of the angles to abscissa considered the two elements of that mechanism ruling sided.

Note

This paper is based on the paper presented at The 1st International Conference "Experimental Mechanics in Engineering" - EMECH 2016, organized by Romanian Academy of Technical Sciences, Transilvania University of Brasov and Romanian Society of Theoretical and Applied Mechanics, in Brasov, ROMANIA, between 8 - 9 June 2016, referred here as [11].

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