SYNTHESIS OF SELF-CENTRING GRIPPERS
/
SINTEZA MECANISMELOR DE PREHENSIUNE AUTOCENTRANTE

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ABSTRACT
The manipulation of cylindrical and spherical parts and blanks by using robots, to move them from a working place to another requires that the gripper fulfils certain conditions. This mechanism must be self-centring, to avoid the deterioration of the robots. In this paper, we made a synthesis of some self-centring grippers, by amplification with simple modular groups, usually RRR dyads. The grippers in the synthesis are considered to be with rigid fingers and with movable catching point.

REZUMAT
Manipularea pieselor si semifabricatelor de formă cilindrică si sferică folosind robotii industriali, pentru a le muta dintr-un loc de lucru in altul, necesita anumite condiţii pentru mecanismul de prehensiune. Acest mecanism trebuie sa fie cu centru de prindere fix, pentru a evita deteriorarea robotilor. În aceasta lucrare este realizata sinteza unor mecanisme de prehensiune cu centru de prindere fix, prin amplificarea cu grupe modulare simple, de obicei diade RRR. Mecanismele de prehensiune pentru care este făcută sinteza sunt considerate a fi cu degete rigide si cu punctul de prindere deplasabil.

INTRODUCTION
Manipulators and industrial robots can manipulate the pieces and blanks of different shapes. In the case of cylindrical or spherical parts or blanks, it is necessary that the gripping mechanism be self-centring, to avoid damaging the robot.

Lately, a lot of studies and researches have been made on the analysis and synthesis of the mechanisms of grippers with rigid fingers for industrial robots or anthropomorphic catching mechanisms (*Azlan N.Z., Yamaura H., 2012; Mesaros-Anghel V. et al., 2016; Chen W., Xiong C., 2016; Tarliman D., 2014; Tilli J. et al., 2014; Zhou X. et. al., 2015; Wu L., Carbone G., Cecarelli M., 2009; Wu L., Kong Y., Li X., 2015).*

In this paper, we will refer only to gripping mechanisms with stiff fingers.

Movements of fingers belonging to gripping mechanisms can be pure rotation, pure translation or planar complex motion.

As a result of this, the gripping centre of cylindrical or spherical parts is movable, depending on the diameter of the parts and on the gripper kinematic dimensions.

Figure 1 shows the kinematic scheme of the mechanisms gripping fingers presented in two different positions. The two fingers are articulated at points A and C and they have prismatic jaws.

The fingers are symmetrically related to axis *OX* and form the angles φ_1, respectively φ_2 with the positive direction of the axis *OX*. The diameters of the two cylindrical parts are *D*1 and *D*2.

The error between the positions of the two centres of the parts is:

$$\Delta L = XO2 - XO1 \tag{1}$$

where:

$$XO1 = R\cos\varphi_1 + BO1\sin\varphi_1$$
$$XO2 = R\cos\varphi_2 + BO1\sin\varphi_2\,; \tag{2}$$

$$BO1 = a + D1/2/\cos\alpha$$
$$BO2 = a + D2/2/\cos\alpha\,; \tag{3}$$

$$\sin\varphi_1 = \frac{-R.\cdot e + BO1\sqrt{BO1^2 + R^2 - e^2}}{BO1^2 + R^2}$$
$$\cos\varphi_1 = \frac{BO1\cdot e + R\sqrt{BO1^2 + R^2 - e^2}}{BO1^2 + R^2} \quad (4)$$

$$\sin\varphi_2 = \frac{-R.\cdot e + BO2\sqrt{BO2^2 + R^2 - e^2}}{BO2^2 + R^2}$$
$$\cos\varphi_2 = \frac{BO2\cdot e + R\sqrt{BO2^2 + R^2 - e^2}}{BO2^2 + R^2} \quad (5)$$

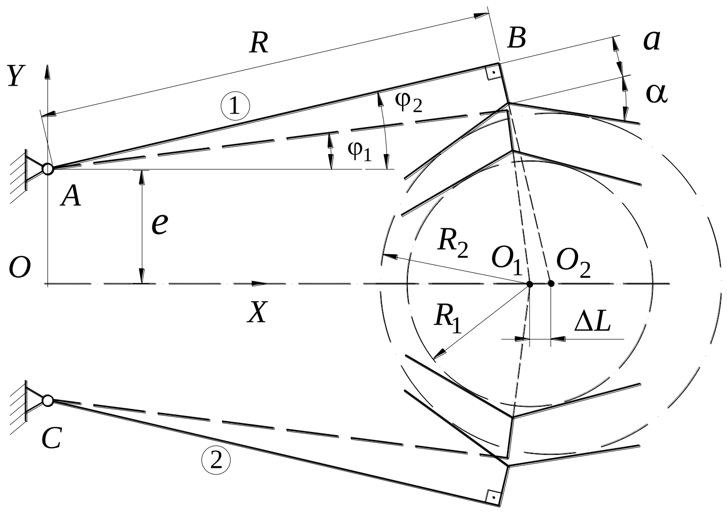

Fig. 1 - Highlighting centres of the cylindrical parts

In the literature related to this field is to be remarked the achievement of various self-centring mechanisms in several ways, namely:

- by kinematic synthesis of the entire mechanism taking into account the self-centring requirements *(Dudita Fl. and Staretu I, 1987; Konstantinov M., 1978; Kovacs Fr. and Cojocari G., 1982; Simionescu et al., 1987)*;
- by the synthesis of cams for actuating jaws in order to fulfil the centring condition *(Huang Qingsen, 1982)*;
- by shaping the caching jaws of the gripping mechanism, so that the gripping centre to remain fixed *(Simionescu et al., 1988).*

MATERIAL AND METHODS

In the present paper, we made a synthesis of self-centring gripping mechanisms, by amplifying the gripper with movable self-centring catching mechanism with simple modular groups, typically RRR dyads.

Figure 2.a shows the kinematic scheme of a gripper with bars, lower pairs and movable gripping centre, and Figure 2.b presents its schematic multipolar diagram.

Considering the multipolar scheme, it results that the gripper contains, besides to base group Z(0), a motohexade with lower pair (motor group with a hexagonal contour).

The mechanism gripping shown in Figure 2 can be transformed into a self-centring gripper, like the one presented in Figure 3, by amplifying it with two dyads RRR, which are designed to guide the nippers of the fingers so that the catching centre to remain fixed for a certain range of diameters of parts to be caught between its fingers.

Determination of elements dimensions contained in the modular groups involves two steps, namely:

a) establishing the old mechanism kinematic parameters for a given number of diameters to be gripped, considering point P as being fixed;

b) synthesis of the new mechanism from the self-centring conditions.

The synthesis equations are determined by using the contour *OT'TDEFPO*. By projecting the vector equation:

$$OT' + \overline{T'T} + \overline{TD} + \overline{DE} = \overline{OP} + \overline{PF} + \overline{FE}\,, \tag{6}$$

on the axes of the coordinates system results the system presented below:

$$\begin{cases} S_i + b - XP + DE\cos\varphi_{3i} + EF\sin(\varphi_{4i} + \alpha - \beta) - \\ \qquad - FP\cos\varphi_{4i} = 0; \\ d + DE\sin\varphi_{3i} - EF\cos(\varphi_{4i} + \alpha - \beta) - FP\sin\varphi_{4i} = 0; \\ i = \overline{1, p}, \end{cases} \tag{7}$$

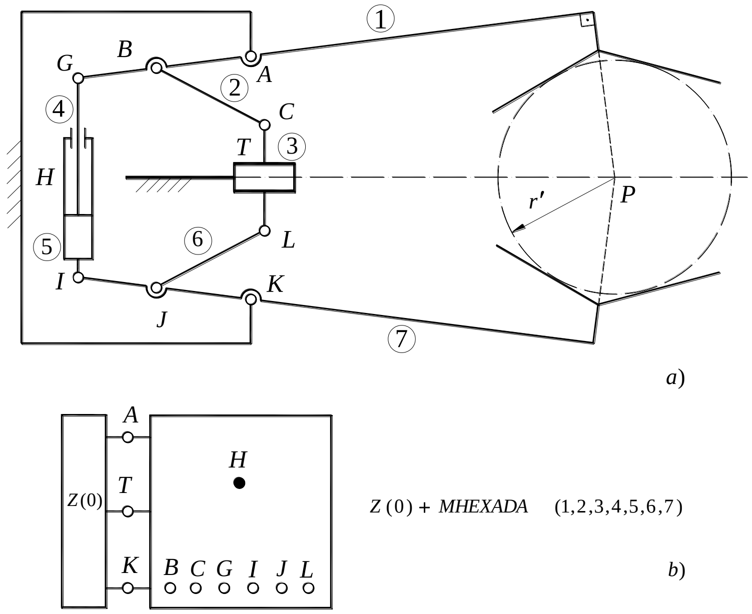

Fig. 2 - Gripper with movable gripping centre depending on the gripping parts diameter
a) kinematic scheme b) multipolar scheme

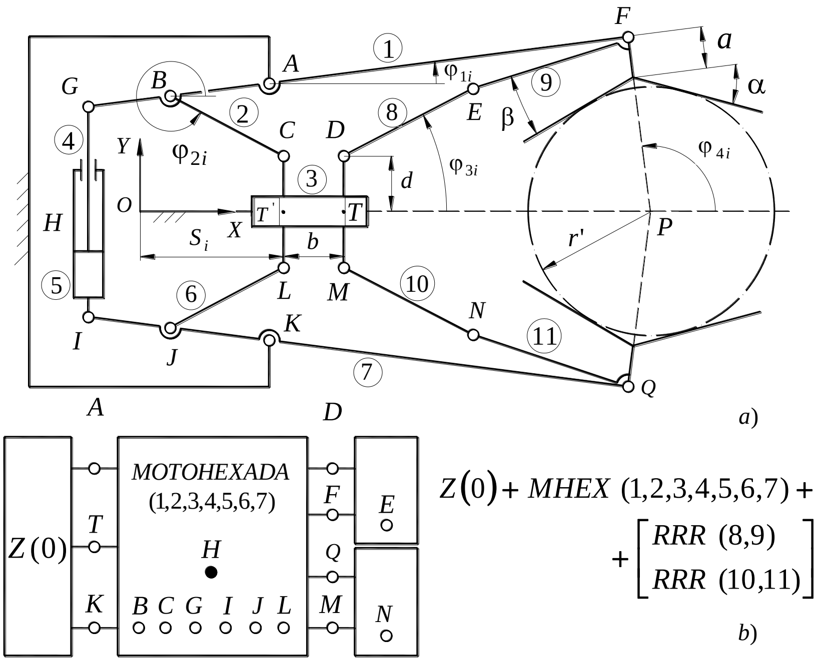

Fig. 3 - Self-centring gripper with bars
a) kinematic scheme; b) multipolar scheme

In the above system, ***p*** represents the number of positions for which the gripping is exact.

We obtained a system of non-linear equations which has the unknowns: *b*, *d*, *DE*, *EF*, β, φ_{3i}, $i=\overline{1,p}$
Starting from the condition of compatibility: 2*p* = 5+*p*, results *p* = 5, so there are 5 possible solutions for which the gripping is done accurately.

The accomplished system of non-linear equations is solved by using an adequate numerical method (Newton-Raphson, gradient etc.); *(Bakvalov, N., 1976; Dorn W.S., Mc Cracken D.D., 1976; Demidovitch, B.P., Maron I.A., 1981)*. The number of system equations can be reduced from 10 equations to 5 equations by eliminating the angle φ_{3i}. In this way is achieved a system of non-linear equations which has the unknowns: *b*, *d*, *DE*, *EF*, β namely:

$$\begin{cases} b11 + 2b1[EF\sin(\varphi_{4i}+\alpha-\beta) - FP\cos\varphi_{4i}] - \\ \quad -2d[EF\cos(\varphi_{4i}+\alpha-\beta) + FP\sin\varphi_{4i}] \\ \quad -2EF.FP\sin(\alpha-\beta)=0; \\ i=\overline{1,p}, \end{cases} \tag{8}$$

where: $b11 = b1^2 - DE^2 + EF^2 + FP^2 + d^2$,

$b1 = b + S_i - XP$.

In figure 4 is presented the kinematic scheme a) and multipolar scheme b), of a self-centring gripper fulfilled from a gripping mechanism with moveable centre and composed from a motor tetrad with bars and gears, amplified with two dyads *RRR*.

The system of equations used for the synthesis of the mechanism is:

$$\begin{cases} XE - XP - EF\cos(\varphi_{1i}+\gamma) + FG\cos\varphi_{2i} - HP\cos\varphi_{3i} - \\ \qquad + HG\sin(\varphi_{3i}+\alpha-\beta)=0; \\ YE - YP + EF\sin(\varphi_{1i}+\gamma) + FG\sin\varphi_{2i} - HP\sin\varphi_{3i} - \\ \qquad - HG\cos(\varphi_{3i}+\alpha-\beta)=0; \\ i=\overline{1,p}, \end{cases} \tag{9}$$

where: *HP = a+D/2/cosa.*

The unknowns of obtained system non-linear equations are: *EF*, *FG*, *HG*, β, γ, φ_{2i}, $i=\overline{1,p}$.
Taking into account the condition of compatibility results the solution p = 5. The variable dimensions φ_{1i}, φ_{3i} are determined previous to synthesis by taking into account the kinematic analysis of the initial mechanism. By eliminating the angle φ_{2i} the nonlinear system is reduced from 10 to 5 nonlinear equations as follows:

$$\begin{cases} b22 + 2EF(HP\cos(\varphi_{1i}+\varphi_{3i}+\gamma) - HG\sin(\varphi_{1i}+\varphi_{3i}+\alpha-\beta+\gamma) + \\ \quad +(XE-XP)\cos(\varphi_{1i}+\gamma) + (XE-YP)\sin(\varphi_{1i}+\gamma)) - \\ \quad -2HP(HG\sin(\alpha-\beta) + (XE-XP)\cos\varphi_{3i} + (YE-YP)\sin\varphi_{3i}) - \\ \quad -2HG((XE-XP)\sin(\varphi_{3i}+\alpha-\beta) - (XE-YP)\cos(\varphi_{3i}+\alpha-\beta)) = 0; \\ i=\overline{1,p}, \end{cases} \tag{10}$$

where:

$$b22 = EF^2 - FG^2 + HP^2 + HG^2 + (XE-XP)^2 + (YE-YP)^2$$

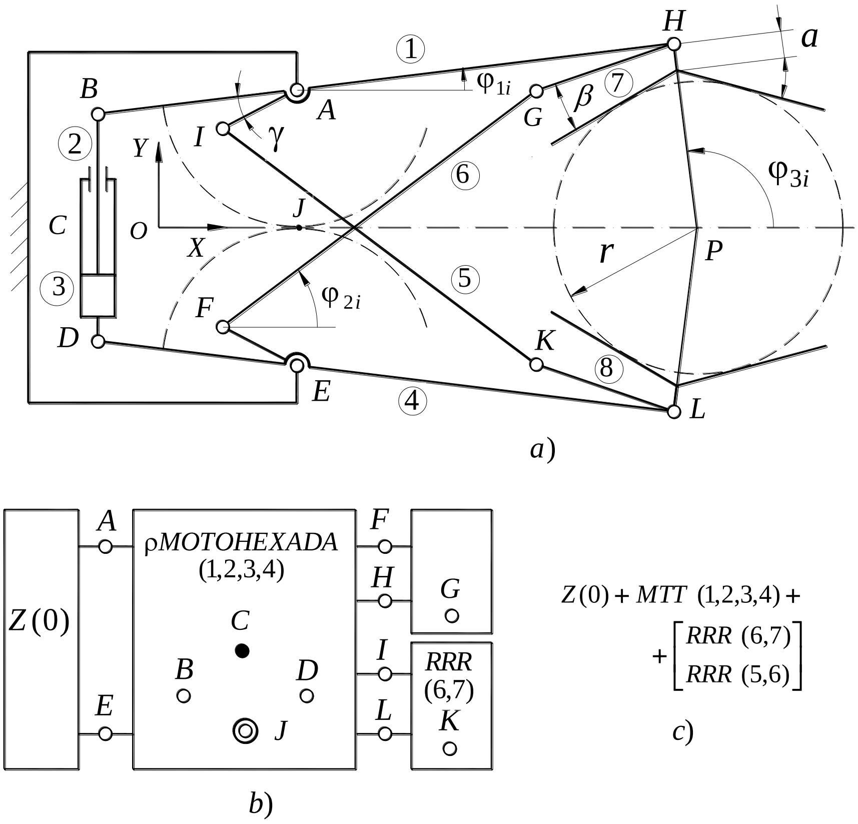

Fig. 4 - Self-centring gripper with bars and gears
a) kinematic scheme; b) multipolar scheme

RESULTS

To convert the gripper with the movable catching centre depending on the diameter of the caught parts into a self-centring gripping mechanism were considered:

- the diameter range of the griped parts between 0.040 and 0.08 [m].
- α = 0.5235987 [rad];
- *a* = 0.010 [m];
- *XP* = 0.165 [m]
- *XA* = 0.065 [m];
- *YA* = 0.040 [m];
- *AB* = 0.030 [m];
- *BC* = 0.053 [m];
- *AF* = 0.102 [m];
- *CT'* = 0.010 [m].

Analysing the mechanism shown in figure 2, the resulted angles are φ_{1i}, φ_{2i} as well as the variable parameter in the prismatic pair T.

Solving the system of linear equations, afferent to the mechanism considered for synthesis, we have:

b = -0.03725 [m];
d = 0.02719 [m];
DE = 0.07294 [m];
EF = 0.05435 [m];
β= 0.52336 [rad].

The results below represent the links dimensions of RRR attached dyad as well as the connection elements with the initial mechanism.

CONCLUSIONS

The method of synthesis presented in this paper allows an easy adaptation of some gripping mechanisms with mobile gripping centre, into ones with fixed gripping centre, by development through simple modular groups, usually RRR dyads.

The presented method is very simple, clear, intuitive and easy to use.

Gripping mechanisms can be used successfully in the construction of agricultural machinery.

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