11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

FAMILY OF ANTHROPOMORPHIC GRIPPERS FOR ROBOTS - DESIGN, COMMAND, CONTROL AND FUNCTIONAL SIMULATION

Staretu Ionel
Transilvania University of Brasov
29 Bd. Eroilor, Brasov
Romania

Bolboe Marian
S.C. INA Schaffler Brasov
Aleea Schaeffler 3,507055 Cristian, Brasov
Romania

ABSTRACT
In this paper one family of anthropomorphic grippers for robots, with two, three and four fingers, is shown and the stages of synthesis, analysis, and design are shown too. Some details about motor, command and control subsystems and a functional simulation with examples are presented too.
Keywords: anthropomorphic gripper, design, functional simulation

1. INTRODUCTION
The anthropomorphic grippers have a mechanical structure similar with the bio-mechanism of the human hand. This mechanical structure has two or more fingers with two or three phalanxes. These grippers have as more advantages: a bigger degree of dexterity, a large domain of flexibility and the possibility to make micro-movements with the grasped object. One family of anthropomorphic grippers has as main structural module the finger (with two or three phalanxes) and two, three, four, five or six fingers in different configurations.
In the paper are shown the stages of synthesis, analysis, design, elements of command and control and a functional simulation for one family o grippers with two, three and four fingers. Each gripper of the family is poly-mobile and the degree of freedom is equal with the number of fingers.

2. STRUCTURAL – CINEMATIC SYSNTHESIS AND ANALYSIS
The mechanical structure, shown in Figure 1, for one finger is a linkage mechanical structure.

2.1. Structural synthesis and analysis
The main criteria for the structural synthesis, in general, can be: the number of fingers, the number of phalanxes, the relative position of the fingers, the degree of freedom of the mechanical structure and the characteristic constructive elements used [1].These criteria were adapted for our family of grippers, in order to obtain a good performance: two, three and four identical fingers or with four fingers in proportion as human fingers, relative position as in Figure 2, degree of freedom M = n (n – the number of fingers), linkage mechanism. Each finger is a poly-contour mechanism with two outside connection L=2 (v_1, F_m; ω_7, M_7 or motor power $P_m= v_1F_m$ and outside power $P_7= \omega_7M_7$) and the degree of freedom M=1. The mechanism has three mono-contour mechanisms (see the graph of Figure 3).The degree of freedom for each mono-contour mechanism is obtained with $M_k = \sum f_i - \chi_k$ (where $\sum f_i$ is the degree of freedom of the joints - f_i= 1 and χ_k = 3 is cinematic degree of the mono-contour k mechanism: k=1,2,3). So, $M_1 = f_A + f_B + f_C + f_D - \chi_1 =$

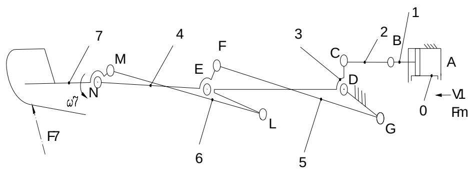


Figure 1. Mechanical structure of the finger

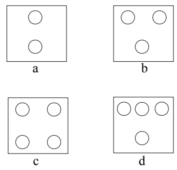


Figure 2. Relative position of the fingers

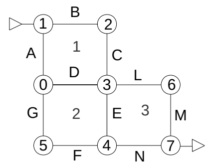


Figure 3. The graph of the mechanical structure

1+1+1+1-3=1,$M_2 = f_D + f_E + f_F + f_G - \chi_2$ =1+1+1+1-3=1, $M_3 = f_L + f_M + f_N + f_E - \chi_3$ =1+1+1+1-3 =1. For the poly-contour mechanism the degree of freedom is obtained with $M = \sum M_k - \sum f_c$ (where M_k is the degree of freedom for mono-contour k mechanism and $\sum f_c$ is the degree of freedom for common joints $\sum f_c = f_D + f_E$=1+1=2.). So, $M = M_1 + M_2 + M_3 - \sum f_c$ = 1+1+1-2=1. ***M=1*** represents: one independent movement (speed): $v_1 = \dot{s}_1$ and one function of the external motor force: $F_m = F_m(M_7)$.
L-M =1 has significance: one function of movement $\varphi_7=\varphi_7(s_1)$ or $\omega_7=\omega_7(v_1)$ and one independent moment: M_7 (generated from gripping force).

2.2 Cinematic synthesis and analysis

The cinematic synthesis is used to obtain a correct closing of the grippers and it is obtained with a good correlation between the dimensions of the phalanxes and o good relative position of the fingers.
For cinematic analysis the vector close chain method is use successively for each mono-contour mechanism [3]. For contour ABCD (Figure 4) the vector equation is:

$$\overrightarrow{AB} + \overrightarrow{BC} + \overrightarrow{CD} + \overrightarrow{DA} = \vec{0} \tag{1}$$

From the scalar system :

$$\begin{cases} l_1 \cos 0 + l_2 \cos\varphi_2 + l_{31} \cos\varphi_{31} + l_{01} \cos\varphi_{01} = 0 \\ l_1 \sin 0 + l_2 \sin\varphi_2 + l_{31} \sin\varphi_{31} + l_{01} \sin\varphi_{01} = 0 \end{cases}, \tag{2}$$

is obtained the function of position: $\varphi_{31} = \varphi_{31}$ (s_1).
For the contour DEFG (Figure 5) the vector equation is:

$$\overrightarrow{DE} + \overrightarrow{EF} + \overrightarrow{FG} + \overrightarrow{GD} = \vec{0} \tag{3}$$

and from the scalar system:

$$\begin{cases} l_{32} \cos\varphi_{32} + l_{41} \cos\varphi_{41} + l_5 \cos\varphi_5 + l_0 \cos\varphi_0 = 0 \\ l_{32} \sin\varphi_{32} + l_{41} \sin\varphi_{41} + l_5 \sin\varphi_5 + l_0 \sin\varphi_0 = 0 \end{cases} \tag{4}$$

the function of position: $\varphi_{41} = \varphi_{41}$ (s_1) is obtained.
For the contour ENML(Figure 6), the vector equation is :

$$\overrightarrow{EN} + \overrightarrow{NM} + \overrightarrow{ML} + \overrightarrow{LE} = \vec{0} \tag{5}$$

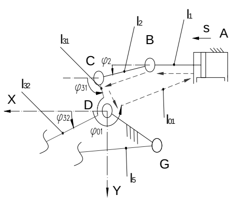


Figure 4. ABCD mechanism and vector contour

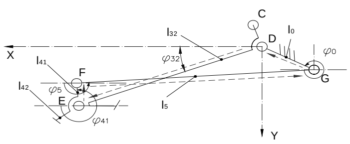


Figure 5.DEFG mechanism and vector contour

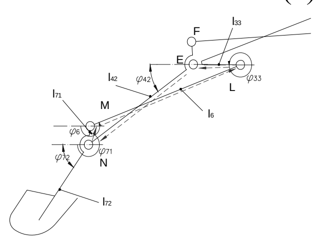


Figure 6. ENML mechanism and vector contour

and from the scalar system:

$$\begin{cases} l_{42} \cos\varphi_{42} + l_{71} \cos\varphi_{71} + l_6 \cos\varphi_6 + l_{33} \cos\varphi_{33} = 0 \\ l_{42} \sin\varphi_{42} + l_{71} \sin\varphi_{71} + l_6 \sin\varphi_6 + l_{33} \sin\varphi_{33} = 0 \end{cases}, \tag{6}$$

the general function of position $\varphi_{71}=\varphi_{71}(s_1)$ is obtained.

The function for speeds are derivative function of time of the function for positions and the function for accelerations are derivative of the function of speed:
The optimum cinematic synthesis is obtained with complex soft as CATIA and with functional simulation of the fingers. CAD model of the finger is shown in Figure 7 and the positions of the dependent joints function of the independent joints is shown in Figure 8.

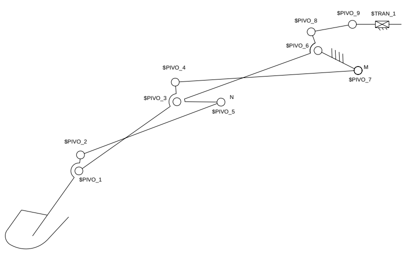


Figure7. CAD cinematic scheme of the finger

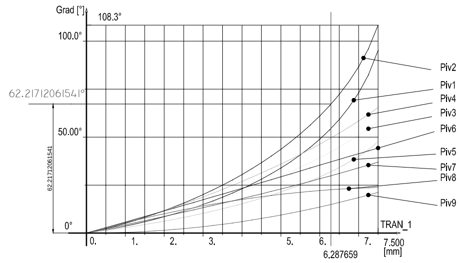
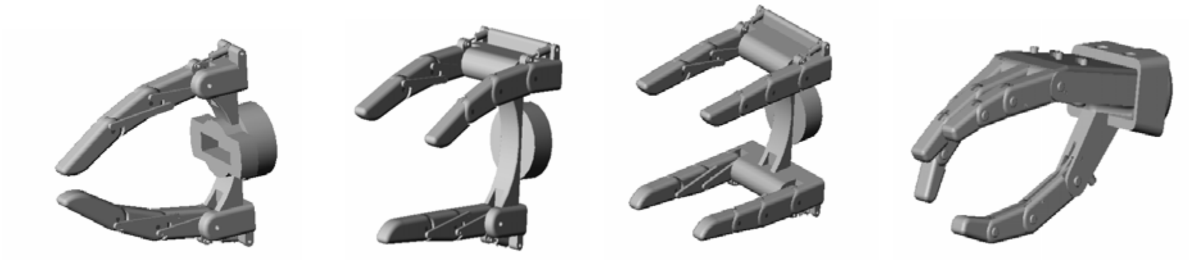


Figure 8. Position of the dependent joints

3. MECHANICAL DESIGN

The grippers from this family have the main following characteristics [2]: linkage mechanisms, fingers with three phalanxes, one pneumatic linear motor for each finger.
Gripper with two fingers(Figure 9,a) has the following characteristics: two fingers, each finger with three phalanxes, degree of freedom M=2, 1,2 :1 in proportional as human hand, proper weight 1,6 kg and useful weight :3,2 kg. Gripper with three fingers (Figure 9,b) has the following characteristics: three fingers, on each finger three phalanxes, degree of freedom M=3, 1,2 :1 in proportional as human hand, proper weight 2,2 kg and useful weight : 5 kg. Gripper with four fingers has two versions : with identical fingers and with fingers in proportional as human fingers. The first version (Figure 9,c) has the following characteristics: four identical fingers, three phalanxes on each finger, , degree of freedom M=4, 1,5 :1 in proportional as human hand, proper weight 4 kg and useful weight : 6,5 kg. The second version (Figure 9,d) has the following characteristics: four fingers(only three in proportional with human fingers), three phalanxes on each finger, , degree of freedom



a b c d

Figure 9. Gripper with 2,3 and 4 identical fingers and 4 fingers in proportional as human fingers (d)

M=4, 1,5 :1 in proportional as human hand, proper weight 5 kg and useful weight : 10 kg.

4. THE MOTOR, COMMAND AND CONTROL SUBSYSTEMS

The motor external force is obtained with the theorem of balance between the powers of entrance and emergence of griping mechanism: $F_m v_1 + M_7\omega_7 = 0$, $Fm = M_7\omega_7 / v_1$. The dimension of the piston of the pneumatic motor will be : $s = F_m/p$(where p is the pressure). For concrete adopted values is selected the motor: DSNU 25-25-P-A-MA-S2.
For command are used the following devices: drossels (LRMA-1/8-QS-8), adapter (SGS-M10x1,5), end component (CPE 14 – PRS –EP), expanding bloc (CPE14 – PRSEO-2), end element (CPE14 – PRSGO – 2), blocked element (CPE14- PRSB).
The control subsystem is make of eight sensors CZN-CP15 type with the following characteristics: -40 C degrees until + 85 C degrees; 0,2 until 100 N grasp force; intensity: 1 Ma; period of life at 35 N:10 million of operations and a signal convector(1 M 36-22 Ex-U).
The general scheme for motor, command and control subsystem for one finger is shown in Figure 10.

The grasp process has the main following stages: start signal for closing the gripper (electro-mechanical , electrical or voice); sensing or not sensing of the object by the tactile sensors; obtaining the grasping force; transfer of the object; open the gripper (similar as the closing stage of the gripper).

5. FUNCTIONAL SIMULATION

A functional simulation was made to check the correct work and to identify the solution to obtain the optimum version for this family of grippers [1.2], for different grasped objects.

Figure 11,a,b,c,d shown the variants with two, three and four identically fingers and Figure 11,e shown the version with fingers in proportional with human fingers (three fingers only).

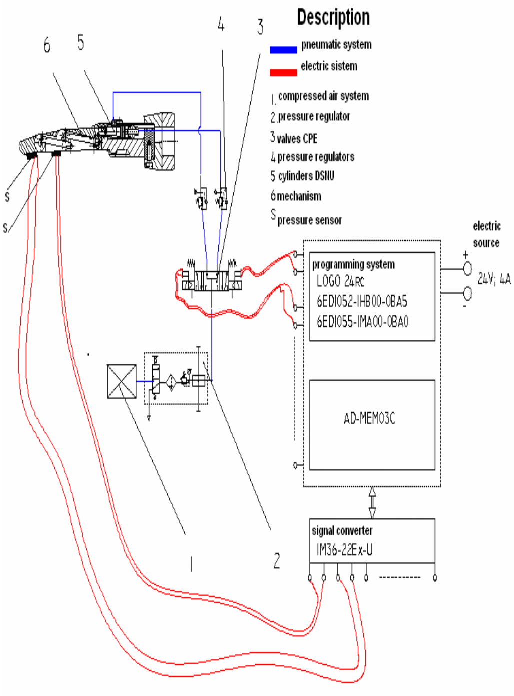


Figure 10. Scheme of the motor, command and control subsystem

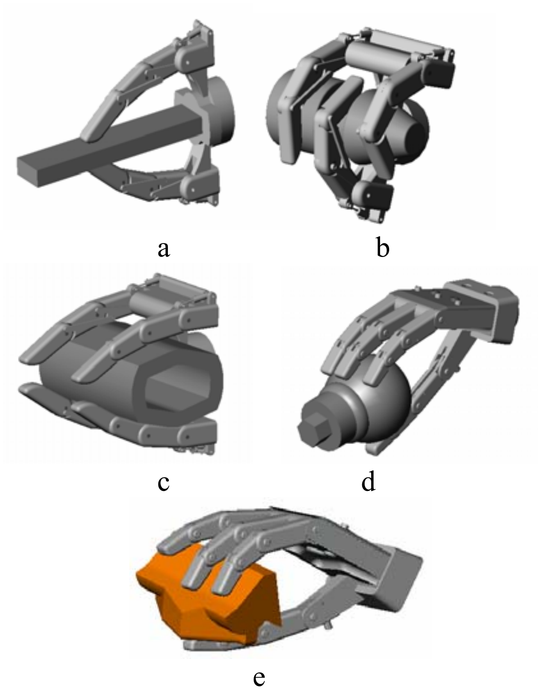


Figure 11. Functional simulation

In the future a virtual simulation will be made and one or two grippers from this family will be mounted on ABB robot for different tests.

6. CONCLUSIONS

Regarding the aspects presented in this paper the following conclusions can be formulated: a)The anthropomorphic grippers described are innovative versions and for all these grippers the complete technical drawings are ready. b) Functional simulation for these grippers is useful for to verified the correct closing and all possibilities to grasp. c) The optimum gripper can be selected function of the grasped object.

7. REFERENCES

[1] Bolboe M., Staretu I., Itu A.: Design, CAD model and functional simulation for an anthropomorphic gripper for robots. In : Proceedings of The 8th International Conference on Mechatronics and Precision Engineering - COMEFIM 2006 - Acta Technica Napocensis, series: Applied Mathematics and Mechanics, 49, vol.II. Cluj-Napoca, Romania,2006.,

[2] Staretu I.,Ionescu M., Runcan V.: Family of Mechanical Anthropomorphic Poly-Mobile Grippers for Robots – Synthesis, Analysis, Design and Functional Simulation. In :Proceedings of the 15th Int. Workshop on Robotics in Alpe-Adria-Danube Region – RAAD 2006, Balatonfured, Hungary. 2006.,

[3] Starețu I., Bolboe M.: The stages for design of the anthropomorphic gripping mechanisms for robots applied at two examples. In: Proceedings of the Intenational Conference on Theory of Machines and mechanisms, Liberec, Czech Republic. 2004.,

[4] Staretu, I.Sisteme de prehensiune(Gripping systems). Lux Libris, Brasov, Romania, 1996.