MODULAR DESIGN FOR A FAMILY OF MECHANICAL ANTHROPOMORPHIC POLY-MOBILE GRIPPERS WITH 4 FINGERS FOR ROBOTS

Ionel Staretu

Transilvania University of Brasov, Product Design and Robotics Department, Brasov, Romania, e-mail:istaretu@unitbv.ro.

Abstract: In this paper one anthropomorphic modular gripper for robots are described. The stages of synthesis, analysis design and functional simulation are presented. The structural synthesis of the anthropomorphic grippers for robots can be made regarding the following main criteria: the number of fingers, the number of phalanxes, the relative dimensions of the phalanxes, the relative position of the fingers, the degree of freedom of the gripping mechanism and the characteristic constructive elements used. We choice a version with four identical fingers with three phalanxes on finger. The kinematic synthesis is used to obtain a correct closing of the finger and of the gripping mechanism. The function of position, the function of speeds and the function of acceleration for characteristic points are obtained from the kinematic analysis. The static synthesis solves the problem to obtaining the necessary gripping force on each finger and the total gripping force. The calculation of strength was made in function of the internal forces which act between elements. With the constructive dimensions a 3D model can be obtained using CATIA soft. Some aspects regarding functional CAD and virtual simulations are shown too. For one variant of this type of gripper, with four fingers, the technical documentation is completed and the technical project has all the conditions for practical achievement. There are two main constructive modules: the support – the palm and the finger.

Keywords: *Robotics, Anthropomorphic grippers, Mechanism, Design, Functional simulation.*

1. Introduction

The mechanical anthropomorphic grippers for robots have as main mechanical component a similar mechanism with the biomechanism of the human hand. This mechanism has only pivot joints and two or more fingers with two or three phalanxes.

These grippers for robots comparatively with others mechanical grippers (mechanical grippers with jaws, mechanical tentacular grippers) have more advantages like: a bigger degree of dexterity (99% for four fingers, 90% for three fingers and 40% for two fingers comparatively with human hand), a larger domain of utility (many types of objects can be grasped) and that the grippers can do micro-movements with the grasped object between the fingers (if the degree of freedom is equal or bigger like the number of fingers).

In the paper are shown the stages of synthesis, analysis, design and simulation for a modulated family of anthropomorphic grippers. There are shown the anthropomorphic poly-mobile grippers with four fingers from this family.

2. Structural Synthesis and Analysis

2.1 Structural synthesis

The structural synthesis can be made regarding the following main criteria: the number of fingers, the number of phalanxes, the relative dimensions of the phalanxes, the relative position of the fingers, the degree of freedom of the gripping mechanism and the characteristic constructive elements used [1,2].

For our family of grippers these criteria were adapted in order to obtain a good performance: four identical fingers, three phalanxes on each fingers, relative position of the fingers like in Fig.1(for 4 fingers), the degree of freedom M=n

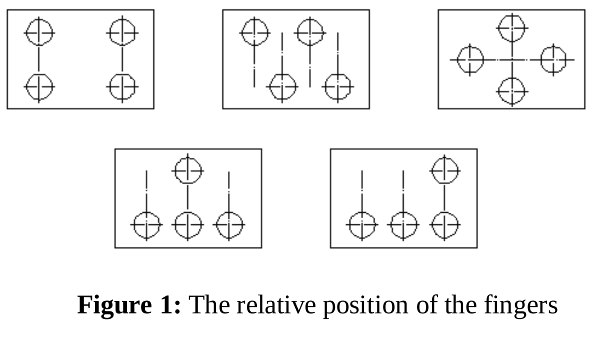


Figure 1: The relative position of the fingers

(n – the number of fingers), linkage mechanisms. The main structural module is accordingly with a finger and it is shown in Fig.2.

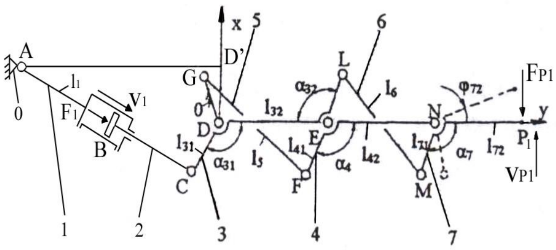


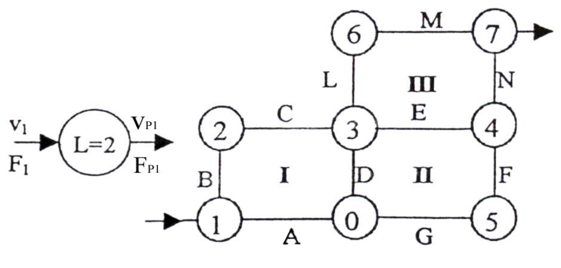
Figure 2: The structural scheme of the finger

2.2 Structural analysis

The mechanism of the finger (Fig.2) is a polycontour mechanism with two outside connection L=2 (v_1, F_1; v_{P1}, F_{P1} – Fig.3,a) and degree of freedom M=1.

The degree of freedom is obtained with $M = \sum M_i - \sum f_c$, where M_i is the degree of freedom for monocontour i mechanism and $\sum f_c$ is the degree of freedom for common joints (Fig. 3,b).

For each monocontour mechanism the degree of freedom is obtained with $M = \sum f_i - \chi_K$ (where $\sum f_i$ is the degree of freedom of the joints and χ_K is kinematic degree of the monocontour k mechanism [1]).



a b

Figure 3: The block scheme and the graph of the mechanism

For the mechanism shown in Fig.2, in accordingly with the graph of Fig.3,b, the following relations are obtained:

$M_I=f_A+f_B+f_C+f_D-\chi_I=1+1+1+1-3=1$

$M_{II}=f_D+f_E+f_F+f_G-\chi_{II}=1+1+1+1-3=1$ (1)

$M_{III}=f_L+f_M+f_N+f_E-\chi_{III}=1+1+1+1-3=1$,

and $\Sigma f_C=f_D+f_E=1+1=2$.

The degree of freedom will be:

$M=M_I+M_{II}+M_{III}-\Sigma f_C=1+1+1-2=1$ (2)

M=1 has the following significance: one independent movement (speed): $v_1 = \dot{s}_1$ and one function of the external forces: $F_1=F_1(F_{P1})$. L-M=1 represents one function of movement: $v_{P1}= v_{P1}(v_1)$ and one independent force: F_{P1} – the contact force between finger and grasped object.

3. Kinematic Synthesis and Analysis

3.1 Kinematic synthesis

The kinematic synthesis is used to obtain a correct closing of the finger and of the gripping mechanism. This situation is obtained with a good correlation between the dimensions of the phalanxes and a good relative position of the fingers. The first and one intermediary position of the finger are shown in Fig.4.

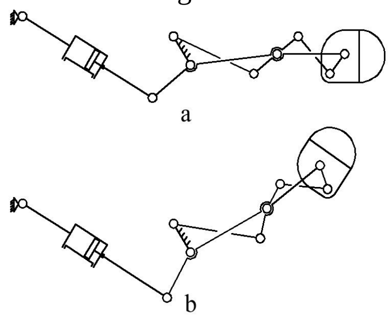


Figure 4: Two configuration of the finger

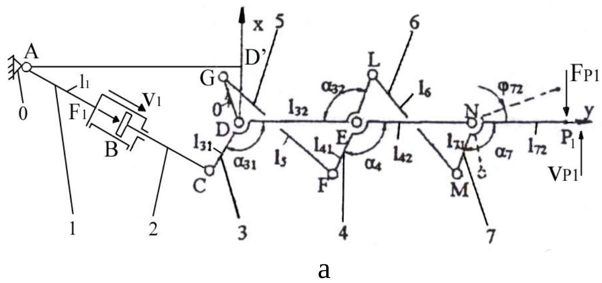
3.2 Kinematic analysis

The function of position, the function of speeds and the function of acceleration for characteristic P_i points are obtained from the kinematic analysis. The vectorial close chain method is use successively for each monocontour mechanism. The vectorial equations are:

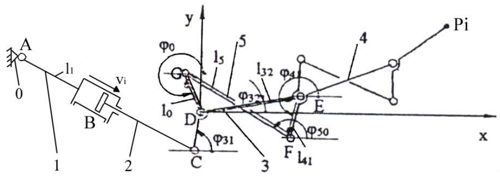
$\overrightarrow{AC}+\overrightarrow{CD}+\overrightarrow{DD'}+\overrightarrow{D'A}=0$ (Fig.5,a),

$\overrightarrow{DE}+\overrightarrow{EF}+\overrightarrow{FG}+\overrightarrow{GD}=0$ (Fig.5,b) and

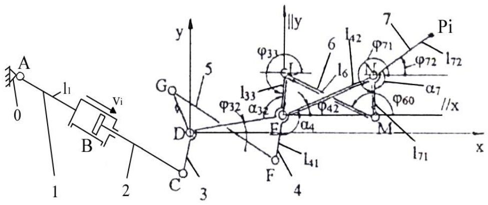
$\overrightarrow{EN}+\overrightarrow{NM}+\overrightarrow{ML}+\overrightarrow{LE}=0$ (Fig.5,c) [3].



a



b



c

Figure 5: The kinematic schemes

The implicit form for the equation of positions is: $\varphi_{72i}= \varphi_{72i}(s_1)$, i- the member of the fingers: i=1,2,3,4.

The functions for speeds are the derivative function of time of the functions for positions and the functions for accelerations are the derivative of the functions for speed:

$$v_{Pi} = \dot{\varphi}_{72i} \qquad (3)$$
$$a_{Pi} = \dot{v}_{Pi}$$

4. Static Synthesis and Analysis

4.1 Static synthesis

The static synthesis solves the problem to obtaining the necessary gripping force on each finger and the total gripping force.

4.2 Static analysis

The function of the external forces is obtained from the theorem of balance between the powers of entrance and emergence of mechanism:

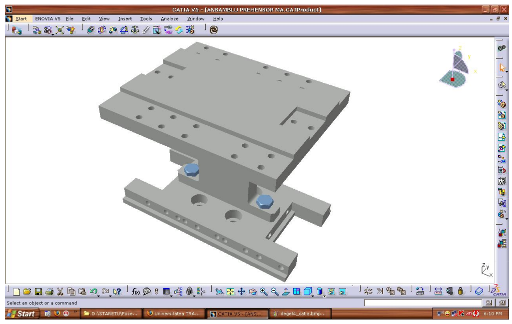
$v_i \cdot F_i + v_{Pi} \cdot F_{Pi} = 0$, and

$$F_i = -\frac{v_{Pi} \cdot F_{Pi}}{v_i} \qquad (4)$$

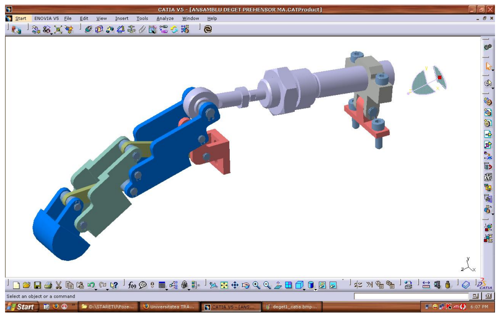
The internal forces are calculated using the theorem of the joints and, after-words, with the balance static equations of the mobile elements [1].

5. Constructive Design and 3D Model

The calculation of strength was made in function of the internal forces which act between elements. With the constructive dimensions a 3D model can be obtained using CATIA soft[6,7]. There are two main constructive modules: the support – the palm (Fig.6,a) and the finger (Fig.6,b)[4,5].



a

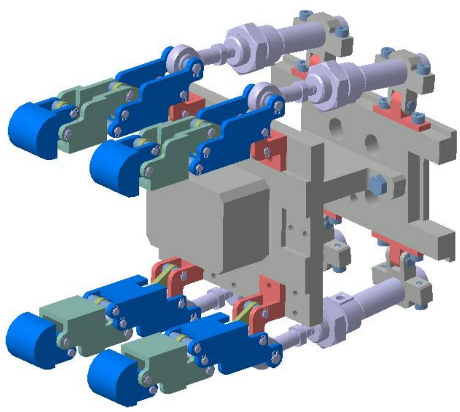


b

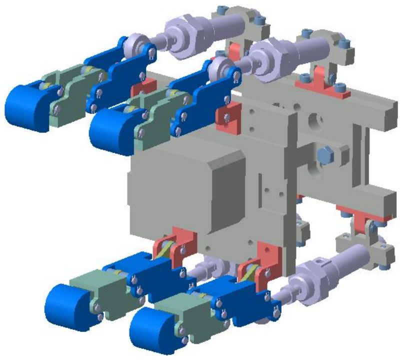
Figure 6: The main constructive modules

The family of anthropomorphic grippers is obtained using fingers in 5 relative positions (see Fig.1).

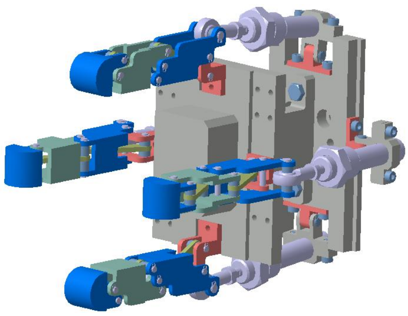
For instance the possible variants with four fingers are shown in Fig.7: one variant with fingers with parallel axes (Fig.7,a); one variant with fingers with parallel axes but with a interval (Fig. 7,b) ; crossing axis (Fig.7,c); three fingers with one



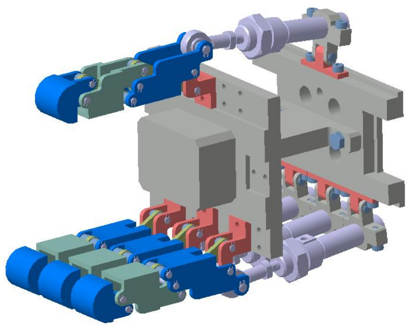
a



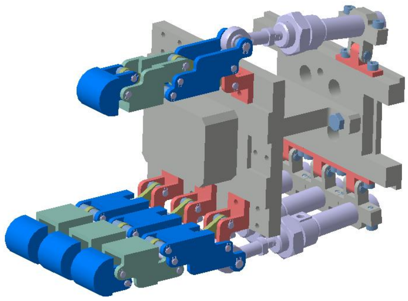
b



c



d



e

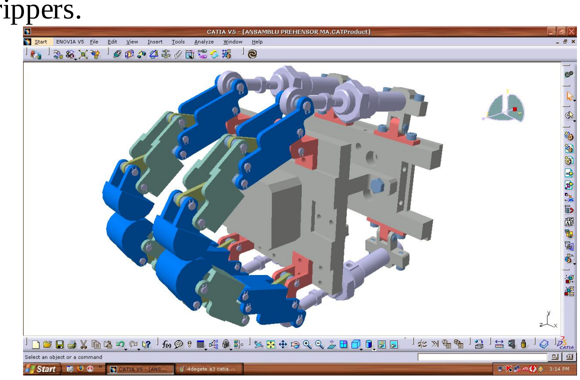
Figure 7: The family of the anthropomorphic grippers with four fingers

in opposite and central position (Fig. 7,d) and three fingers with one in opposite and lateral position (Fig. 7,e).

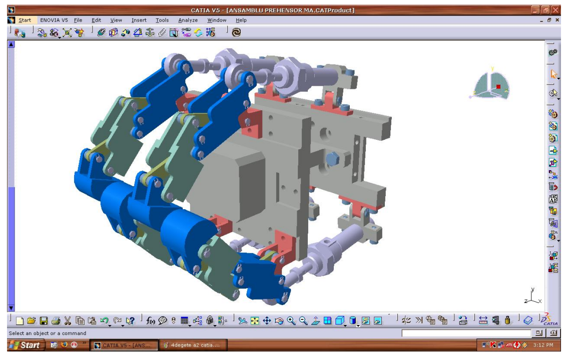
For these five variants the technical documentation is completed and the technical project has all the conditions for practical achievement.

6. Functional Simulation

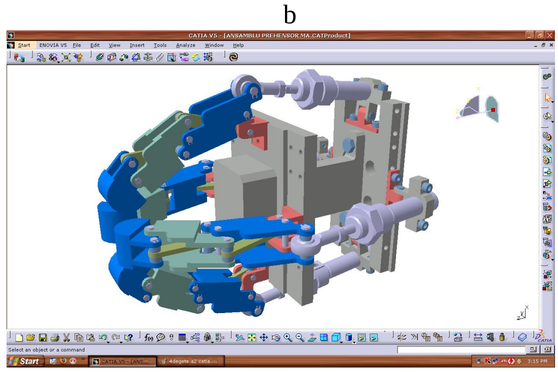
A functional simulation (Fig.8,a,b,c) was made to check the correct work and to identify the solutions to obtain the optimum variant for this grippers.



a



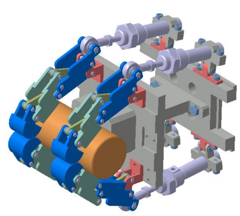
b



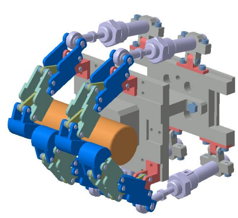
c

Figure 8: The functional simulation

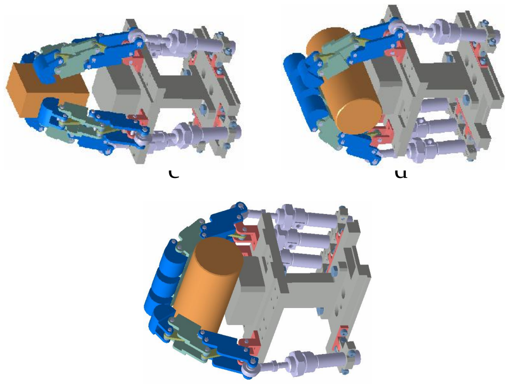
Other functional simulation is made with a piece(Fig.9). These gripper has four degree of freedom and its can grasp objects with regular or irregular forms.



a



b



e

Figure 9: The functional simulation with piece

This gripper, with one specific intermediary piece, can be mounted on any industrial commercial robot(see Fig. 10) . One of its configuration can be obtained, during the gripper is mounted on robot, with change the relative position of the fingers, regarding the form of the grasped object.

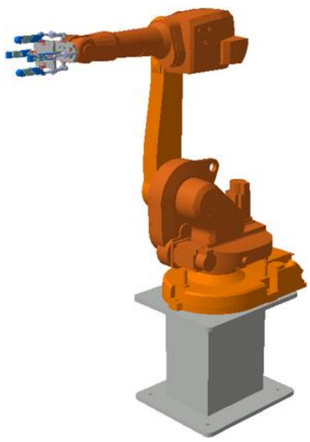


Figure 10: Example with the gripper mounted on ABB robot

For functional simulation of the grasped operations, the robot with the gripper were transferred in virtual reality –VRML soft (Fig.11).

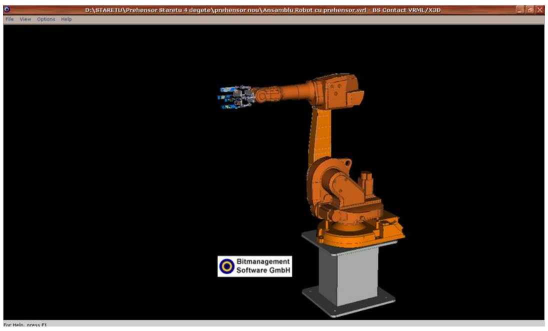


Figure 11: Transfer robot with gripper in VRML soft

Here we can test different grasping operation for different objects. Then, the results, for one correct grasp, can be used for programming the real gripper

7. Action and Command Scheme

7.1 Action scheme

The gripper is acted with four pneumatic motors. 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. The pneumatic scheme is shown in Fig. 12.

7.2 Command scheme

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).

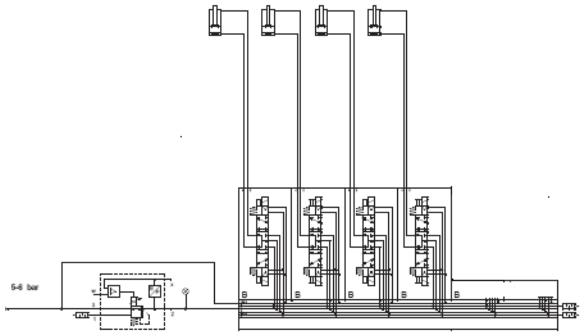


Figure 12: Pneumatic scheme

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 Fig. 13.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).

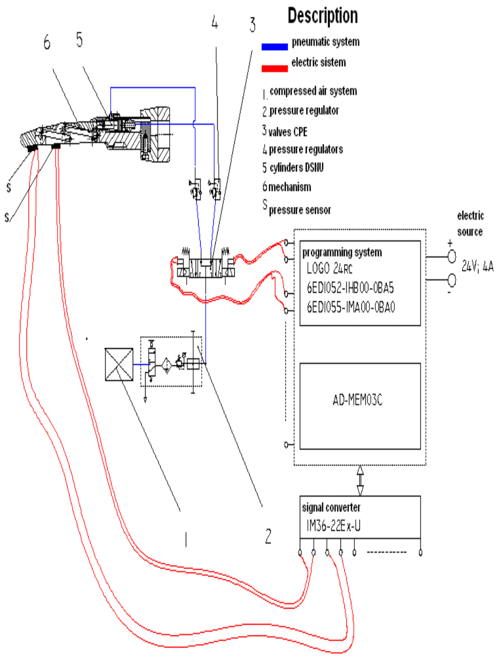


Figure 13: Command and control scheme

8. CONCLUSIONS

The next conclusion can be formulated in according to the considerations presented:

a) The main stages for to design the anthropomorphic mechanical grippers are: structural synthesis and analysis, kinematics synthesis and analysis, static synthesis and analysis, constructive design and 3D model and functional simulation.

b) These grippers can be obtained using two main modules: the support – the palm and the finger.

c) The family of the mechanical anthropomorphic grippers for robots with two, three, four and five identically fingers has more variants, what can be obtained in accordance with the number and the relative position of the fingers.

d) The aspects shown in this paper can be used at families of the anthropomorphic grippers with more than four fingers, with five or six identical fingers.

e) Each finger can be acted with one pneumatic motors and for command and control can be used one classical command scheme.

References

[1] Staretu, I., Daj, I. *Mechanisms and Machine Elements* (in Romanian), Ed. Lux Libris, Brasov, Romania, 2000.

[2] Staretu, I., *Gripping systems* (in Romanian), Ed. Lux Libris, Brasov, Romania, 1996.

[3] Staretu, I., a.a. *Mechanical Hand. Anthropomorphic Gripping Mechanism for prostheses and robots (in Romanian)*, Ed. Lux Libris, Brasov, Romania, 2001.

[4] STARETU, I., BOLBOE, M., *Synthesis, Analysis, Design and Functional Simulation for a Family of Anthropomorphic Grippers for Robots*, Proceedings of the SISOM 2007, pp. 131-134, Bucharest, 29-31 May, Romania.

[5] STAREȚU, I., *Anthropomorphic Gripping Systems with Jointed Bars or Wheel and wires for Industrial Robots – Constructive Synthesis, Analysis and Design, New Trends in Mechanisms*, Editors S.M. CREȚU and DUMITRU N. Academica-Greifswald Publishing House, 2008, pp. 133-144.

[6] STAREȚU,I., *Sisteme de prehensiune (Gripping Systems)-editia a II-a*, Ed. Lux Libris, Brașov, 2010.

[7] STAREȚU,I., *Gripping Systems*, Derc Publishing House, Tewksbury, Massachusetts,U.S.A., 2011.

.