Family of Mechanical Anthropomorphic Poly-Mobile Grippers for Robots - Synthesis, Analysis, Design and Functional Simulation

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Abstract: *The paper presents a family of the mechanical anthropomorphic grippers for robots. The stages of synthesis, analysis design and functional simulation are presented too. For two variant of this family the technical documentation is completed and the technical project has all the conditions for practical achievement.*

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

I 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 micromovements 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 three fingers from this family.

II STRUCTURAL SYNTHESIS AND ANALYSIS

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 [2].

For our family of grippers these criteria were adapted in order to obtain a good performance: two, three or four identical fingers, three phalanxes on each fingers, relative position of the fingers like in Fig. 1, the degree of

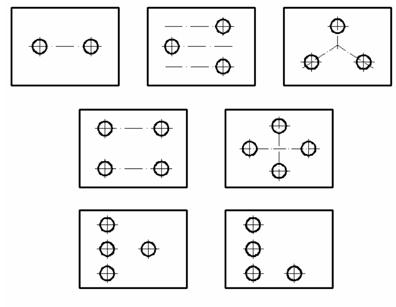


Figure 1
The relative position of the fingers

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

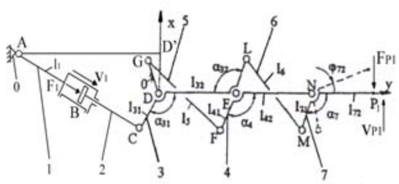


Figure 2
The structural scheme of the finger

Structural Analysis

The mechanism of the finger (Fig. 2) is a poly-contour mechanism with two outside connection L=2 (v_1, F_1; v_{P1}, F_{P1} – Fig. 3a) 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 mono-contour i mechanism and $\sum f_c$ is the degree of freedom for common joints (Fig. 3b).

For each mono-contour 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 cinematic degree of the mono-contour k mechanism [1]).

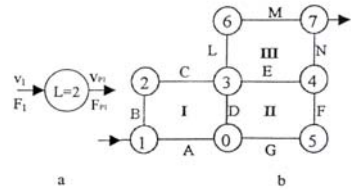


Figure 3
The block scheme and the graph of the mechanism

For the mechanism shown in Fig. 2, in accordingly with the graph of Fig. 3b, 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.

III KINEMATICS SYNTHESIS AND ANALYSIS

Kinematics Synthesis

The kinematics 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.

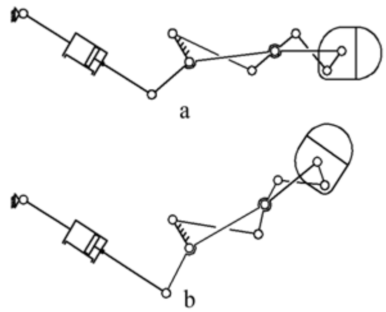
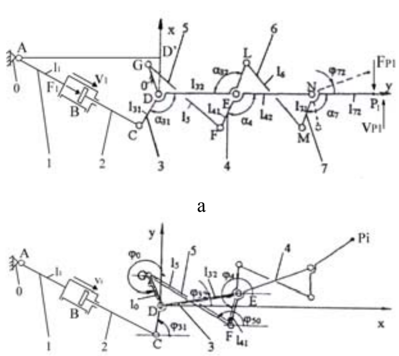


Figure 4
Two configuration of the finger

Kinematics Analysis

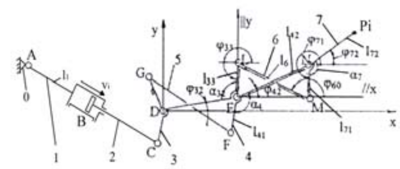
The function of position, the function of speeds and the function of acceleration for characteristic P_i points are obtained from the kinematics analysis. The vector close chain method is use successively for each mono-contour mechanism. The vector equations are: $\overrightarrow{AC}+\overrightarrow{CD}+\overrightarrow{DD'}+\overrightarrow{D'A}=0$ (Fig. 5a), $\overrightarrow{DE}+\overrightarrow{EF}+\overrightarrow{FG}+\overrightarrow{GD}=0$ (Fig. 5b) and $\overrightarrow{EN}+\overrightarrow{NM}+\overrightarrow{ML}+\overrightarrow{LE}=0$ (Fig. 5c) [3].



a

b

Figure 5
The kinematics scheme



c

Figure 5
The kinematics scheme

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:

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

IV STATIC SYNTHESIS AND ANALYSIS

Static Synthesis

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

Static Analysis

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

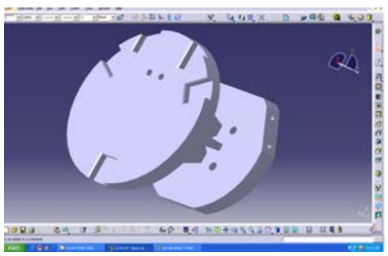
$v_i \cdot F_i + v_{Pi} \cdot F_{Pi} = 0$, and

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

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

V 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.
There are two main constructive modules: the support – the palm (Fig. 6a) and the finger (Fig. 6b).



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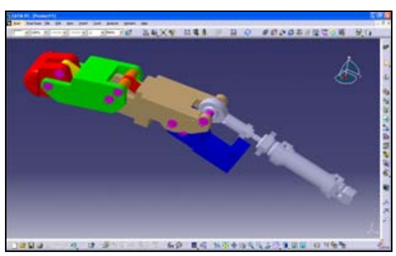

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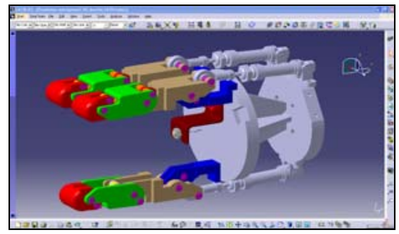
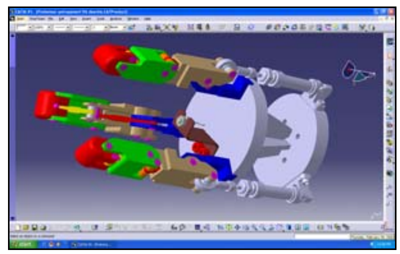
Figure 6
The main constructive modules

The family of anthropomorphic grippers is obtained using 2, 3 or 4 fingers in 7 relative positions (see Fig. 1).
For instance the possible variants with three fingers are shown in Fig. 7 one variant with fingers with parallel axes (Fig. 7a) and one variant with fingers with crossing axis (Fig. 7b).
For these two variants the technical documentation is completed and the technical project has all the conditions for practical achievement.



a

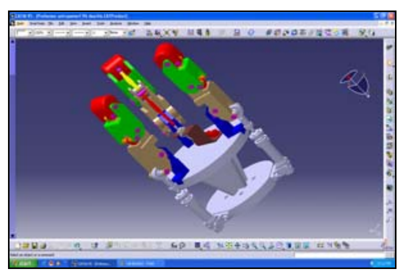


b

Figure 7
The family of the anthropomorphic grippers with three fingers

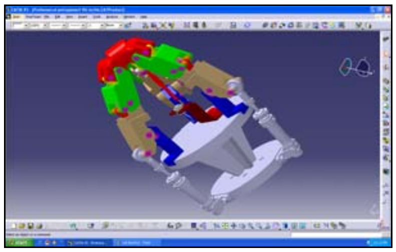
VI FUNCTIONAL SIMULATION

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



a

Figure 8
The functional simulation



b

Figure 8
The functional simulation

Conclusion

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 or four identically fingers has 7 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.

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