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STRUCTURAL SYNTHESIS, ANALYSIS AND DESIGN OF THE MODULAR ANTHROPOMORPHIC GRIPPERS FOR INDUSTRIAL ROBOTS

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Abstract: *Anthropomorphic grippers for robots are similar to human hand and they can have two, three, four or more fingers, with two or three phalanxes. Anthropomorphic grippers for robots compared to other mechanical grippers have more advantages like: a higher degree of dexterity, a larger area of utility (more types of objects can be grasped) and a micro-movement of the grasped objects can be performed. This paper describes one group of modular mechanical anthropomorphic grippers with two versions, with three fingers and with four fingers, designed under coordinating of the author and there are shown more modular solutions. Synthetic, the stages of synthesis, analysis, design and functional simulation are shown too.*
Keywords: *anthropomorphic gripper, modular gripper, structural synthesis, cinematic analysis, functional simulation.*

1. INTRODUCTION

In general, the gripping systems are complex mechatronic systems used by robots, especially by industrial robots, for gripping operations on different pieces, to handle and transfer them from an initial position to a final one that is associated with a robotised action or technological process. In function of the gripping force type, the main categories of gripping systems are mechanical systems, vacuum systems and magnetic systems. In robotics field, mechanical gripping systems are also known as bilateral systems because the grasp is performed using at least two opposite forces onto the piece that is gripped.
Mechanical gripping systems have as main component a mechanical structure, a mechanism that provides the arrangement of the piece’s contact elements towards the piece and enhances the contact force that is the necessary gripping force. In function of the constructive features of the mechanical structure, there are three main types of mechanical gripping systems: with jaws, with fingers (anthropomorphic) or with tentacles [1, 2, 3].
In present industrial robots use especially mechanical gripping systems with jaws, but anthropomorphic ones have become more and more popular, as simple shaped pieces grasped is replaced by grasp and micro handling of complex shaped pieces [4].
Current, anthropomorphic mechanical gripping systems with fingers can have two, three, four, five, or even six fingers with joints, having two or three phalanxes.
In this paper one category of anthropomorphic mechanical grippers, modular with jointed fingers, is described, and it was manufactured based on jointed bar mechanisms, more simple and with acceptable functionality like good alternative at very complex anthropomorphic mechanical hand with very high cost[5,6,7,8], what are in present on the market.

2. ANTHROPOMORPHIC MECHANICAL GRIPPERS

2.1. Main general aspects

Similar as in the mechanisms of prostheses, kinematic items most commonly used are the linkages[9]. They are found primarily in the construction of the fingers. For the rest of the mechanism, in addition to the mentioned elements, common mechanisms elements, of general mechanical transmission (gears, cams), usually smooth

mechanical transmissions, are used[4]. Peculiarities of optimization for elements and couplings used in the robot gripping anthropomorphic mechanisms are arising from their structural features and construction, in the number of fingers, number, and relative position of the phalanges.In terms of optimizing the elements, because there may be more than three finger phalanxes, they must be very flexible but resistant, with similar or even identical forms. Results obtained by design optimization are used.
In the optimization of couplings, in addition to poly-couples use, it is envisaged the adoption of various structural forms that are no longer limited by the size of the model hand, as for the prostheses mechanisms.The phalanges that compose fingers can have the same size, different relative size or size that is proportional to the hand fingers size. Concerning the relative positioning of fingers, it can be similar to human hand; fingers can be placed in a plane, or in different planes. The relative position, depending on the number of fingers, at least two, must be chosen so that their access space is maxim. Several possible versions of relative positioning are illustrated in Fig. 1, of which it is very easy to obtain 3D fingers arrangement versions[2,4].
From the mobility degree point of view, all the fingers are usually actuated independently therefore, the mobility degree equals the number of fingers.

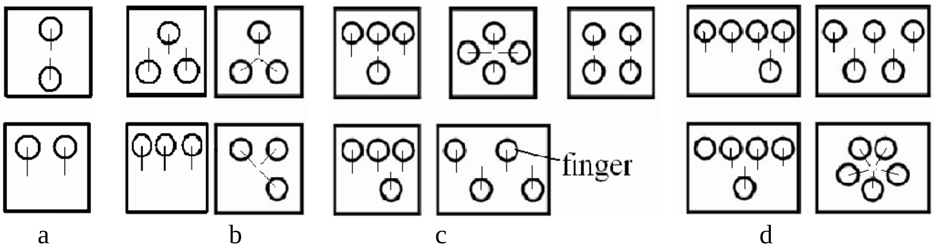


Figure 1: Relative positions of the fingers

In Fig. 2, there are fingers, of three, four and five phalanxes derived from the structural module mechanism. It is represented by the plane anti-parallelogram mechanism.

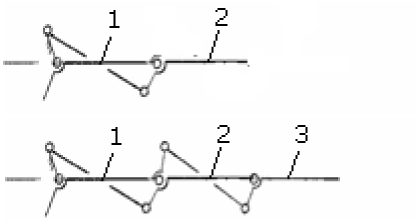


Figure 2: Modular fingers: with two or three phalanxes

2.2. Structural and cinematic synthesis and analysis

In the case of these mechanical grippers, the finger (Fig.3) is made by connecting more jointed bar mechanisms, in general anti parallelogram ones, according to the number of phalanxes (two or three)[11].

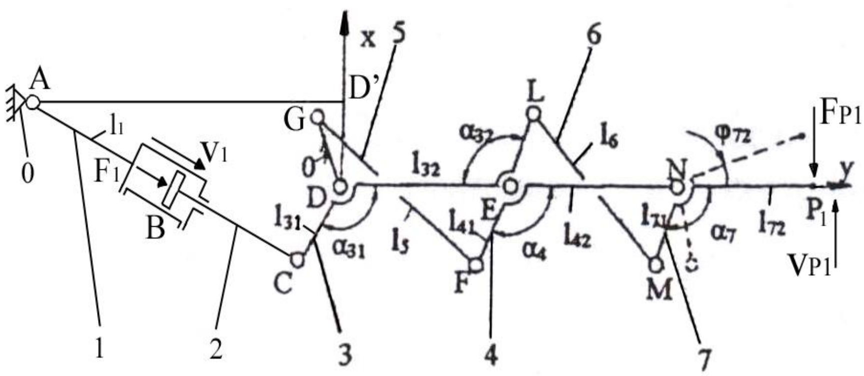


Figure 3: The structural scheme of one finger

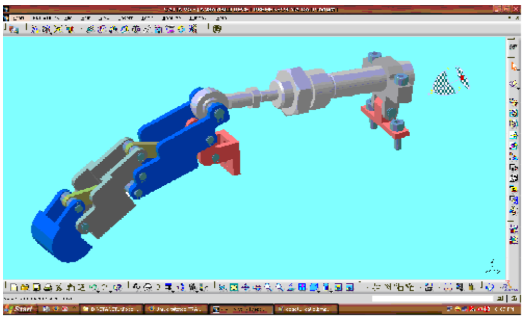
Through **structural synthesis** the configuration of the finger is established that is the driving mechanism type and the number of phalanxes and the number of anti parallelogram mechanisms connected.
During the following stage, a **structural analysis** is performed in order to check if the mechanism is defined from the operational point of view (the mobility degree is determined, the cinematic and static parameters that are independent are identified, as well as the functions that convey external movements and forces).
For the mechanism in Fig.4, the mobility degree for each mono-contour mechanism is determined using the formula [3]: $M_k = \sum f_i - \chi_k$ (where $\sum f_i$ is the mobility degree of the couples - $f_i = 1$ and $\chi_k = 3$ is the cinematic rank of the mono-contour mechanism k=1, 2, 3). So, $M_1 = f_A + f_B + f_C + f_D - \chi_1 = 1+1+1+1-3=1$, $M_2 = f_D + f_E + f_F + f_G - \chi_2 = 1+1+1+1-3=1$, $M_3 = f_L + f_M + f_N + f_E - \chi_3 = 1+1+1+1-3 = 1$. For the multi-contour mechanism, the mobility degree is determined using the formula: $M = \sum M_k - \sum f_c$ (where M_k is the mobility degree for the mono-contour k and $\sum f_c$ is the mobility degree of the common couples $\sum f_c = f_D + f_E = 1+1=2$.). Therefore, $M = M_1 + M_2 + M_3 - \sum f_c = 1+1+1-2=1$.

M=1 represents an independent movement (independent speed): $v_1 = \dot{s}_1$ and a function that conveys external force: $F_m = F_m(M_7)$.
L-M =1 means a function that conveys external movement $\varphi_7 = \varphi_7$ (s_1) or $\omega_7 = \omega_7$ (v_1) and an independent momentum M7 (generated by the gripping force).

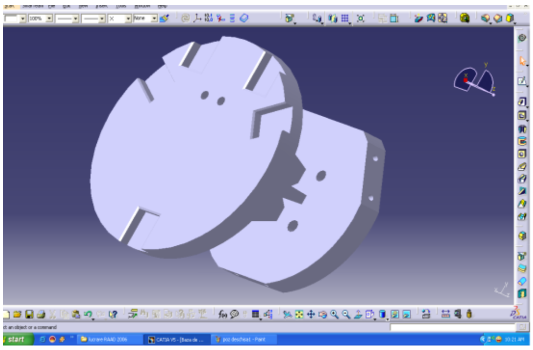
The cinematic synthesis means to adopt linear and angular dimensions necessary for the correct closing of the gripping system, and for the correct relative movements of the fingers, in order to grip the group of pieces given.
The cinematic analysis is performed using the method of the closed vector contour, applied successively to the vector contours corresponding to the mono-contour mechanisms underlined in Fig. 3.

3. DESIGN OF THE MODULAR MECHANICAL GRIPPERS

Under author's coordination the modular grippers designed are based on two modules, namely: a finger and a base (the palm). Two families that differ in structural features of the finger and platforms were designed. See Fig. 1, there are four gripping structures(a,b,c,d) obtained by the relative positioning of two, three, four or five identical fingers[12,13].
In Fig.1, the structural scheme of the finger is shown and the constructive form for this structural acheme is illustrated in Fig. 4a. Grippers in the family are based on a platform (palm) for three-finger versions (Fig. 4b) and another platform (Fig. 4c) for four-finger versions.



a



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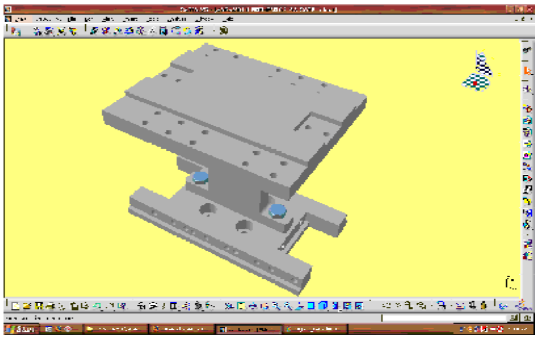
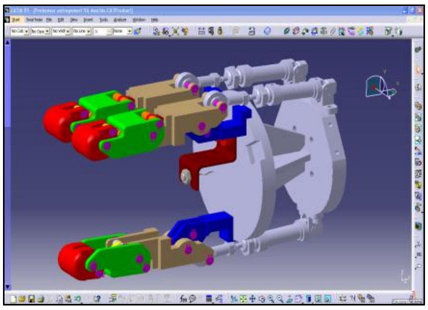


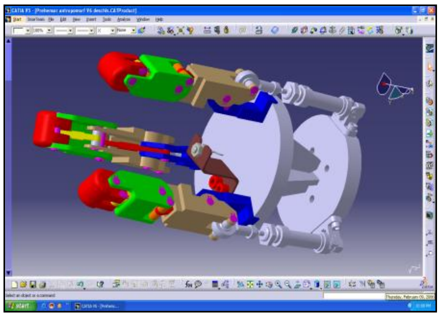
c

Figure 4: Constructive modules

Used these modules two main three-finger versions can be obtained (see Fig.1b and Fig. 4), the fingers having possible parallel (Fig. 5a) or concurrent movements (Fig. 5b). In Fig. 5c for the second situation, the gripper closing is simulated and in Fig. 5d a prototype, ready to be tested, is shown.



a



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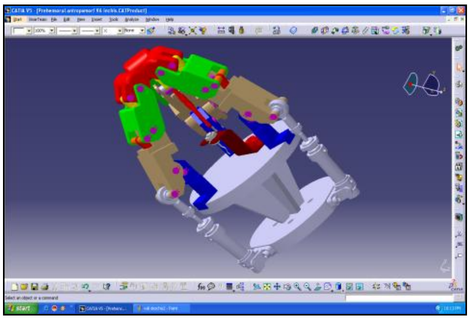
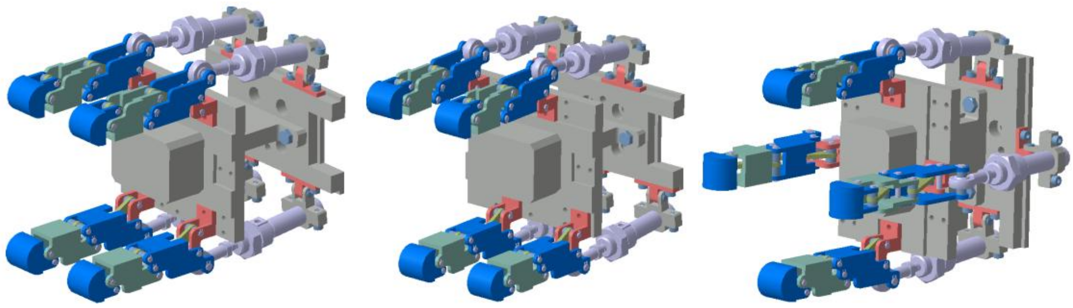


c

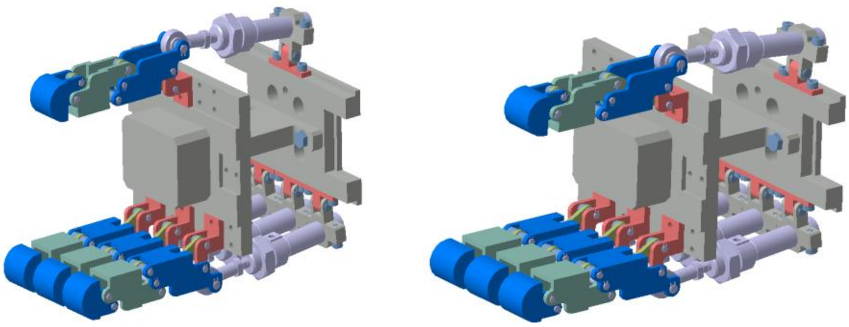
d

Figure 5: Modular anthropomorphic grippers' family with three fingers: the two main configurations(a and b), CAD simulation(c) and one prototype(d)

Technical characteristics of this prototype are: degree of freedom: M=3; weight hand: 12 N; payload: 40 N; gripping force: ~ 30 N/finger; dimensions: finger: 1:1 human fingers size and hand: 140x140x100 mm.
For four fingers modular mechanical anthropomophic gripper there are 5 variants (see also Fig. 1c), illustrated in Fig. 6.



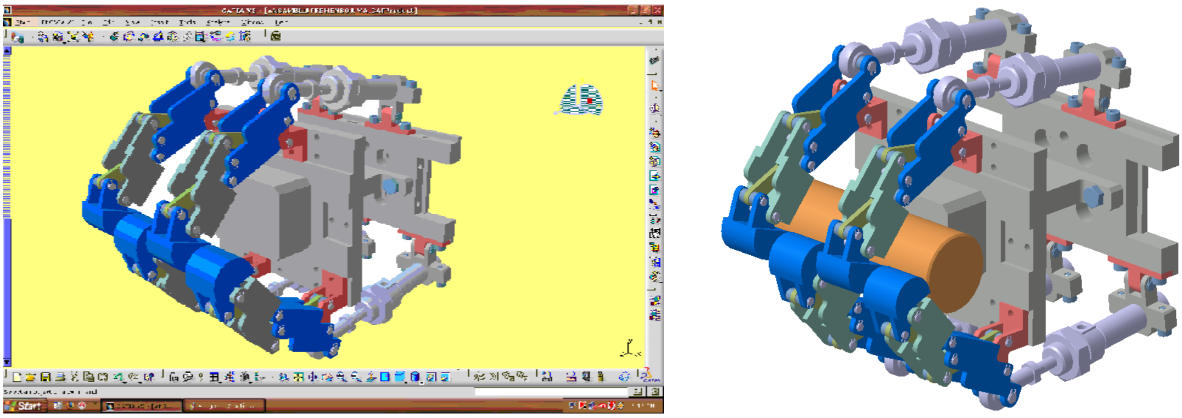
a b c



d e

Figure 6: Modular anthropomorphic grippers' family , wth four fingers

In Fig. 7 is illustrated the gripper closing for the fingers intercalated parallel trajectories variants, without any piece to grip (Fig. 7a) and with a piece to grip (Fig. 7b).



a b

Figure 7: Modular versions closing CAD simulation,
four fingers, with no entity to grip (a), with entity to grip (b)

In this situation each finger is actuated by a pneumatic linear motor so that the degree of mobility of the grippers equals the number of fingers. Contact sensors are provided for the fingers, mounting them on the phalanges, and appropriate control equipment is used. Grippers can be mounted on the robot arm through the flange at the platforms base and they use the robot's sources of energy. For to change the gripper configuration (depending on the range of parts to grip) is possible without the gripper disassembling, only by changing the finger or the fingers position. With these grippers' families, a variety of parts can be gripped and they can successfully replace more sophisticated and highly expensive anthropomorphic grippers[6]. Similar, of the two basic versions, based on three, respectively, four fingers variants with two fingers, respectively, five and even six fingers can easily derive.

4. CONCLUSIONS

The main conclusions are as follows, In according with the ideas described in this paper:
- anthropomorphic gripping systems (with fingers) are used more and more frequently for industrial robots;
- there are one main type of anthropomorphic mechanical grippers (with fingers) according to their constructive elements : with jointed bars –linkages;
- there are two main types of anthropomorphic mechanical grippers, what can be classified in two groups: classical mechanical anthropomorphic grippers and modular mechanical anthropomorphic grippers;
- the synthesis and the structural and cinematic analysis of these gripping mechanisms can be done using classical methods that are popular in the theory of mechanisms, correspondingly adapted.

- functional simulation, in CAD software of these gripping mechanisms allows their constructive optimization and their use in order to perform the given gripping operations.

REFERENCES

[1] Doroftei, I., Robotics(in Romanian), vol. 1 and 2 , Iasi, Technique, Scientific and Didactical Publishing House, CERMI, 2005-2006.

[2] Staretu, I., Gripping Systems(in Romanian), Brasov, Lux Libris Publishing House, 2010.

[3] Staretu, I., Gripping Systems, Tewksbury, Massachusetts, Derc Publishing House, 2011.

[4] Staretu, I., Neagoe, M., Albu, N., Mechanical Hands. Anthropomorphic Gripping Mechanisms for Prostheses and Robots(in Romanian), Brasov, Lux Libris Publishing House, 2001.

[5] Kawasaki, H., Komatsu, T., Uchiyama, K., Dexterous anthropomorphic robot hand with distributed tactile sensor: Gifu hand II, IEEE/ASME Transactions on Mechatronics, 2002, 7 (3), pp. 296-303.

[6] http://www.barrett.com.

[7] http:// www.shadowrobot.com /products/, 2013.

[8] http://www.bebionic.com/wp-content/uploads/bebionic-Product-Brochure-Final.pdf.

[9] Belter, J. T., Segil, J. L., Dollar, A.M., Weir, R. F., Mechanical design and performance specifications of anthropomorphic prosthetic hands: A review, Journal Rehabil Res. Dev.,2013, 50 (5), pp.9-618.

[10] Staretu, I., Anthropomorphic Gripping Systems with Jointed Bars or Wheels and Wires for Industrial Robots-Constructive Synthesis, Analysis and Design, New Trend in Mechanism, Editors: S.-M.Cretu and N. Dumitru, Academica-Greifswald PH,2008, Germany, pp.133-144.

[11] Bolboe, M., Stareţu, I., Itu, A., Design, CAD Model and Functional Simulation for an Anthropomorphic Gripper for Robots. The 8th International Conference on Mechatronics and Precision Engineering, Cluj – Napoca, 2006, pp. 15-20.

[12] Staretu, I., Ionescu, M., Runcan, V., Family of Mechanical Anthropomorphic Poly-Mobile Grippers for Robots – Synthesis, Analysis, Design and Functional Simulation. The 15th International Workshop on Robotics in Alpe- Adria- Danube Region, Balatonfured, June 15-17, 2006, pp. 271-277.