MODELLING AND SIMULATION WITH MSC ADAMS OF A 5-FINGER AND 3-PHALANX / FINGER UNDER-ACTUATED MECHANICAL HAND

Prof. Dr. Eng. Gheorghe **POPESCU, -** “Constantin. Brâncusi” University of Târgu Jiu, e-mail: gepo@utgjiu.ro

Abstract:*This paper studies the modelling and simulation with MSC ADAMS of a 5-fingered and 3-phalanx/finger under-actuated mechanical hand, designed by the author to work on industrial robots.*

Moreover, in order to increase grasping safety in the automated handling process, the author has fitted each finger with a locking sequence in the final phase of grasping.

Thus, the mechanism of mechanical hand is considered to be a mechanical system and is treated like a set of rigid bodies connected by mechanical linkages and elastic elements.

To model and simulate this mechanism with MSC ADAMS programme, the author covered the following stages: construction of the model, testing-simulation, validation, finishing, parameterization, and optimization

Key words: Modelling, simulation, mechanical hand, under-actuated finger, proximal phalanx, medial phalanx, distal phalanx, isotropic force, self-locking.

1. INTRODUCTION

With a view to carrying out certain technological operations, a series of movements which ensure circulation and correct placement of semi-fabricates and/or pieces in front of working tool is performed. This set of movements is also known as handling.

Passing from handling performed by human operator to automated handling represent one of the main issues of industrial production automation.

Therefore, in the last years the problem regarding ***creation of systems of typified equipments intended for automated handling*** of pieces became a first preoccupation of construction of technological systems companies.

In order to surpass this lack of success (mainly because of costs needed for the control of the architecture of complex mechanical systems with many actuation elements, plus numerous sensors), a special emphasis has been laid on the decrease of number of degrees of freedom, concomitantly with the decrease of the number of actuations. These solutions drew away from the performances of human hand and, as a result, solutions have been searched in order to decrease the number of actuations without decreasing the degrees of freedom.

This approach in the paper [1], referred to as *under-actuation*, uses passive elements like springs or mechanical limits leading to a mechanical adaptation of the finger to the shape of an object to be grasped. Starting from these considerations, in this paper is presented the result of a dynamic analysis with MSC ADAMS of the mechanism of a mechanical model with 5 fingers and 3 phalanxes/finger, of the type which appear in the paper [1], but to which has been attached a new type of under-actuation designed by the author [2]. In addition, in order to increase grasping safety in automated handling process, the author fitted each finger with a self-locking sequence on opening in the final phase of grasping.

2. ENSURING GRASP STABILITY IN THE FINAL CLOSING SEQUENCE

In order for an object to have an optimal grasp two conditions need to be met:

- the grasp has to be stable, being impossible to eject the object under the last phalanx;
- the difference which appears between the three phalanxes should be zero or close to minimum.

In this case, the isotropic force $\boldsymbol{F_{iz}}$ is defined as being the particularity of a finger to generate equal contact forces over all its phalanxes:

$$F_{iz} = F_p = F_m = F_d . \qquad (2.1)$$

where:

$\boldsymbol{F_p}$ - contact force on the proximal phalanx;
$\boldsymbol{F_m}$ - contact force on the medial phalanx;
$\boldsymbol{F_d}$ - contact force on the distal phalanx.

This particularity is the most important when the question arises relating to prevent lesions on the grasped object caused by the unbalanced distribution of grasping forces.

Equal contact forces over all phalanxes on a finger can be achieved only by the optimization of finger's design.

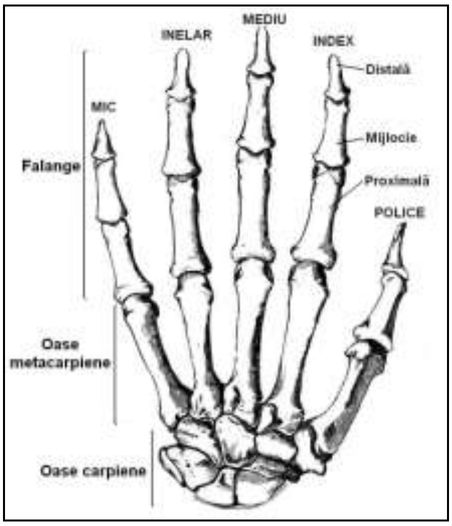

Figure 1. Structure of human hand.

These requests are entirely fulfilled by the human hand.

From the structural standpoint, (figure 1), human hand consists of 27 bones: 8 carpal bones, 5 metacarpal bones and 14 phalanxes (two in the thumb (pollex) and three phalanxes - proximal, medial, (middle) and distal – in other fingers).

Except these, human hand has several actuations consisting in a rich network of muscles and ligaments which allow a big flexibility and accuracy.

For prehension and robotized handling under conditions of safety of objects under the shape of pieces, we have conceived an experimental model of articulated under-actuated 5-fingered hand. The hand has been designed with 15 degrees of freedom and a single actuation with screw, fitted with a hydraulic system for compensation of efforts between fingers. The constructive details and the functioning manner have been presented in the paper [2].

Figure 2. Test stand carried out by the author.

In figure 2 is presented the carried out test stand. The results of the experiments led to the conclusion that through the under-actuation of this articulated mechanical hand, the final closing sequence sometimes performed an instable grasp. This phenomenon could happen as result of the occurrence of negative forces [2]. We could draw the conclusion that if the proximal force in phalanxes is negative, the last phalanx shall loose contact with the object, being initiated a sliding process.

For robotic fingers, a very well defined purpose is to have the configuration of the isotropic force adequate to the typical grasped object. Moreover, the final grasp stability must be ensured.

But grasped objects can have different shapes. In order to ensure grasp stability in the final sequence of closing too (self-locking of distal phalanx on opening), we have modified the configuration of proximal phalanx so that the position of elements $\boldsymbol{8_d}$, ***9*** and ***10*** be in extension (figure 3).

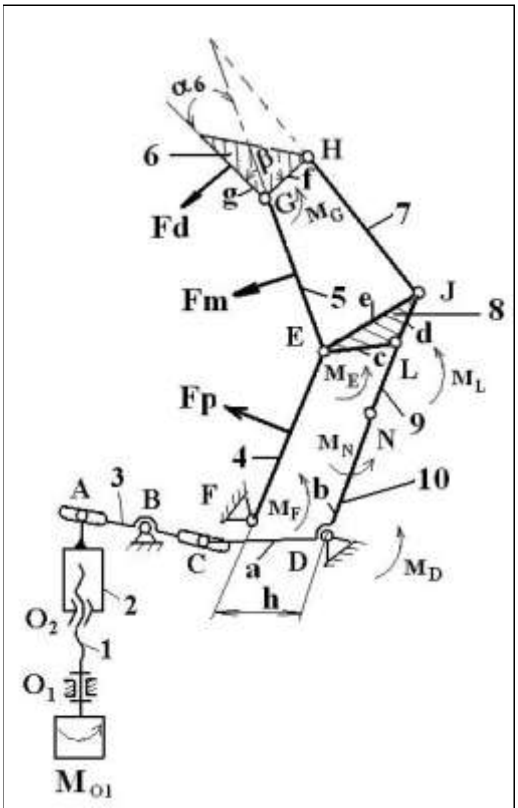

Figure 3. Kinematic diagram of an under-actuated finger, with self-locking sequence.

In compliance with the kinematic diagram in figure 3, for an under-actuated finger, we have decided that the actuation of $\boldsymbol{M_E}$ rotation be applied to the input of middle phalanx and be transmitted further on to the distal phalanx through suitable mechanical elements. The experimental model of a finger has been also designed with passive elements to kinematically constrain the finger and ensure the shape-adaptation of the finger to the grasped object. The actuation torque $\boldsymbol{M_D}$ is applied to coupling ***D***, and this one transmits the effort to all phalanxes.

3. MODELLING WITH MSC ADAMS OF PREHENSION MECHANISM WITH 2 FINGERS AND 3 PHALANXES

To model contact forces, we have started from the hypothesis that in the process of functioning of mechanical hand, the most part of the received energy is used to carry out the closing operation. The mechanism of the mechanical hand with 5 fingers and 3 phalanxes/finger has been considered a mechanical system and has been dealt in ADAMS like a set of rigid bodies (called parts), connected by mechanical linkages (called couplings) and elastic elements.

Over the bodies within the mechanical system of the mechanical hand mechanism have been imposed initial conditions of position – orientation, which have been taken into account in the assembling process [5,6].

For the modelling and simulation of the mechanical hand mechanism with ADAMS programme, we have considered two opposite fingers (figure 4), similar to the kinematic diagram in figure 3. In this model are known the geometric sizes of the elements which enter the structure of fingers and the actuation system, as well as the assembled configuration of hand mechanism.

The geometrical sizes of an under-actuated finger are presented in table 1.

Table 1. The geometrical sizes of an under-actuated finger

	l_4 [mm]	l_5 [mm]	l_6 [mm]	a [mm]	b [mm]	c [mm]	d [mm]	e [mm]	f [mm]	g [mm]
Finger	63	42	32	23	41	14	42	28	13	32

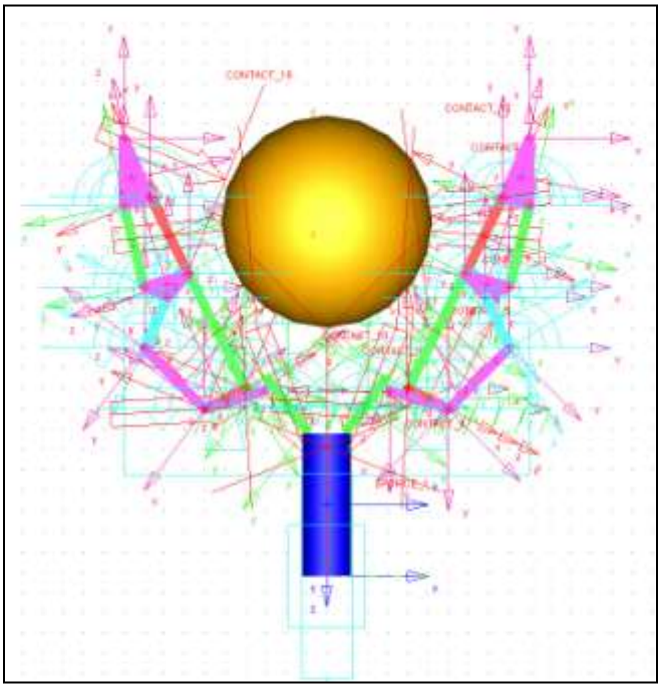

Figure 4. Model in Adams/View of the mechanical hand.

Modelling based on MSC ADAMS software, model Adams/View, lies on the principles of solid modelling [7]; to this effect, are automatically determined the mass, the inertia tensor and the centre of mass position of modelled elements.

The mechanism couplings have been implemented using the coupling software library, by indicating the connections between different components of the carried out model and the fixed part of basis type. In the following stage have been modelled the contacts between some elements of the chain drive and between the phalanx and the grasped object. Eventually, has been modelled the linear motor and an actuation force of 1000 N has been applied on it. The connexions between different elements of the model, exterior loading and the linear motor are concisely presented in figure 5.

Input parameters used to carry out simulation are as follows: geometrical sizes and assembled configuration of hand mechanism, diameters and coordinates of grasped object, rotation angle of the actuator arm, actuator force and rate of travel of linear motor.

Taking into consideration the variable character of some input parameters (presented above), the following remarks are to be made:

- the actuator force and the actuator rate of travel of linear motor have been chosen constant;
- the rotation angle of the drivind element $\boldsymbol{l_1}$ has been chosen variable, depending on the diameter of the grasped object (between 0^o at the beginning of simulation and the maximal value of 67^o at the end of the time interval needed for simulation, when the coupling formed by elements 9 and 10 in on the interior dead point, and the elements are in extension);
- the diameter of the grasped object has been chosen between Ø = 102 mm şi Ø = 140 mm, with increasing sequences of 40 mm;

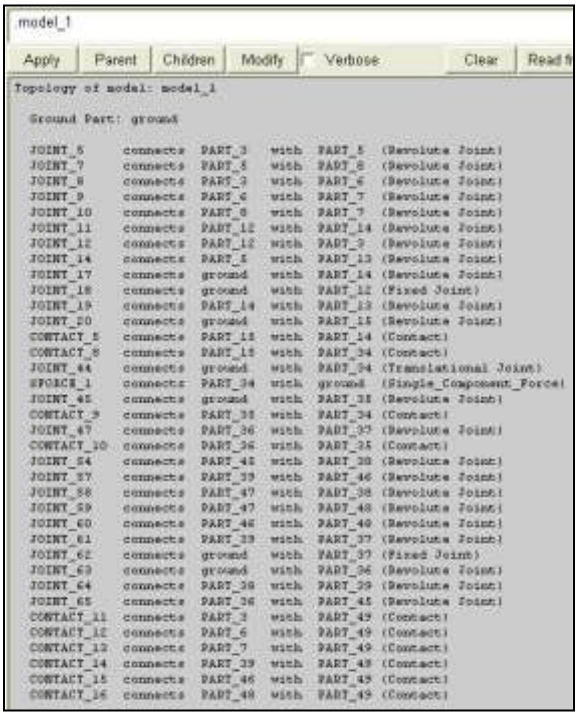

Figure 5. Connexions between different elements of the model, exterior loading and linear motor.

Figure 6. Result of the verification of created model.

- the duration of simulation has been correlated with the diameter of the grasped object and getting of phalanxes self-locking in the closed hand position;

Before starting the simulation, the verification of the created model has been carried. By verification, the software automatically displayed the results presented in figure 6.

4. RESULTS OF SIMULATION

Simulation of the created model aims as follows:

- the grasp has to be stable in the sense that ejection of the object under the last phalanx should be prevented;

- getting of contact forces equal over all phalanxes of a finger;
- the grasping final sequence finishes with self-locking of distal phalanx;
- optimization of the design of mechanical hand elements;
- optimization of grasping.

5. CONCLUSIONS

Modelling with MSC ADAMS of the 5-finger mechanical hand mechanism and simulation of its closing led to the following conclusions:

- Information on the grasp stability and ejection of the object under the last phalanx can be obtained.
- Conditions where final grasping sequence is concluded with self-locking of the distal phalanx can be set;
- Information on the size of contact forces between fingers phalanxes and diameters of the object to be grasped can be obtained;
- Optimization of the mechanism of kinematic diagram construction can be done;
- Grasping can be optimized.

REFERENCES

[1] Lionel Birglen, Clément Gosselin, *Optimal Design of 2-Phalanx UnderactuatedFingers.* International Conference on Intelligent Manipulation and Grasping, Gênes, Italie, pp. 110-116, Juillet 2004.

[2] Gheorghe Popescu: *New solutions for compensation tightening efforts between your fingers of one hand robotics*, Annals of the „Constantin Brâncuşi " University of Târgu - Jiu,Engineering Series, Issue 4/2011, Editura "Academica Brâncuşi" , Târgu Jiu, ISSN 1842-4856, pag 33.

[3] Gheorghe Popescu: *Dynamic analysis of a crimping device with multiple cams using MSC ADAMS – Part. II – Shaping of the tightening forces from a crimping device with multiple cams, using MSC ADAMS.* Fiabilitate si Durabilitate - Fiability & Durability no 1/ 2012, Editura "Academica Brâncuşi" , Târgu Jiu, ISSN 1844 – 640X, pag. 82.

[4] Jula, **A.** *Multibody modeling of the tripod coupling*. Proceedings of Research and Development in Mechanical Industry – RaDMI 2002, vol.2, VrnjaOka Banja, Yugoslavia, 1 – 4 september 2002. p. 649 – 654.

[5] Alexandru, C. *Virtual prototyping of mechanical systems used to the renewable energy sources.* Proceedings of the First Conference on Sustainable Energy – CSE, Braşov, pag. 69 (Abstract Book), 2005.

[6] Bernard, A. *Virtual Engineering: Methods and Tools.* Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, Vol. 219 (5), 2005, p. 413-421.

[7] ******* *Getting Started using ADAMS v2011*, MSC Software, 2011.