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

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Abstract:*This paper studies the analysis 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

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

In this case, 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

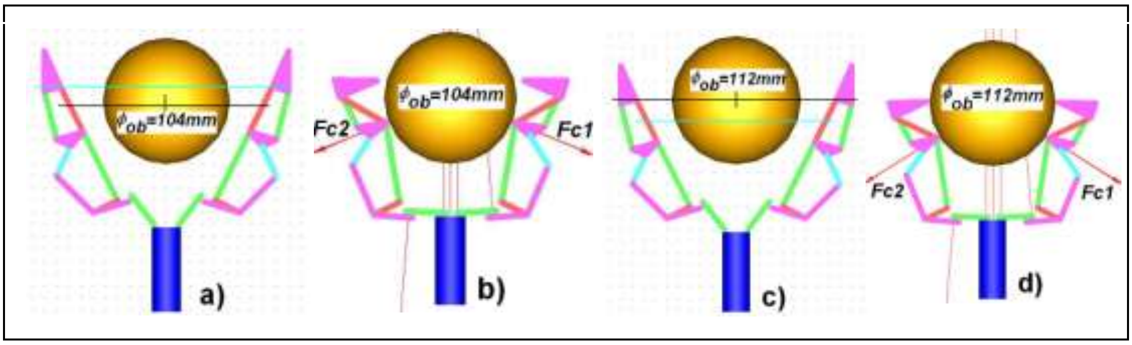

Figure 1. Position of symmetry axis of grasped object towards symmetry axis of middle phalanx.

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. ANALYSIS OF GRASP STABILITY

In this case we have considered the following two aspects:

- factors which influence ejection of the object under the distal phalanx;
- factors which influence the carrying out of equal contact forces over all phalanxes of a finger.

As for the ejection of the object under the distal phalanx, simulation with MSC ADAMS demonstrated that the responsibility is borne by its diameter and its coordinates of disposition towards the middle phalanx. If for the sizes of the finger in table 1 (previous work) diameter of grasped object is lower than 105 mm and its symmetry axis coincides with the symmetry axis of the middle phalanx (figure 1a), the proximal phalanx shall grasp the object in exterior, like in figure 1b. It is interesting the remark in figure 2 where in a simulation cycle, the middle phalanx executed a negative rotation of 105^{o}, the distal phalanx executed a positive rotation of 136^{o} without making contact with the object, and the proximal phalanx executed a positive rotation of 22^{o} and ejection of the object to exterior. The final sequence of simulation is presented in figure 1b.

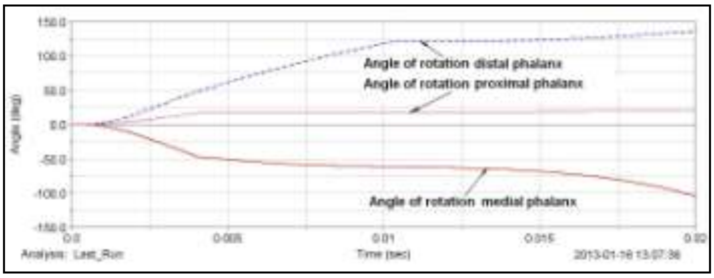

Figure 2. Rotation angle of the 3 phalanxes of a finger, on a simulation cycle.

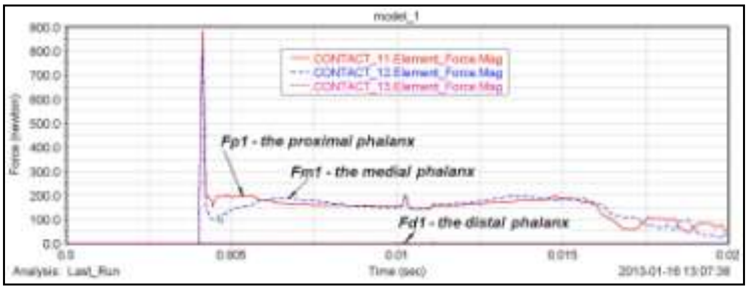

Figure 3. Variation of contact force F_{p1} to eject the object under the proximal phalanx of finger 1.

If for the same sizes of the finger the symmetry axis of the object is placed on the same coordinate with the upper extremity of the middle phalanx, (figure 1c), then its ejection is possible for diameters lower than 115 mm, (figure 1d). The responsibility for this phenomenon is borne by the same proximal phalanx. In figure 3 is presented the variation of contact force F_{p1} to eject the object under the proximal phalanx of finger 1. Out of the figure it is seen that the distal phalanx does not generate a contact force, because it does not make contact with the object to be grasped.

Moreover, it has been found out that grasp stability is obtained only for diameters higher than 124 mm, but lower than 140 mm.

3. ANALYSIS OF DISTAL PHALANX SELF-LOCKING

As for the distal phalanx self-locking to execute the operation of handling of a grasped object, need to be met two conditions:

- elements in figure 3, (part I), which are encompassed in couplings N and L must be in extension; so that any force inversely applied to the contact area of the distal phalanx not to perform its opening and drop of the grasped object.

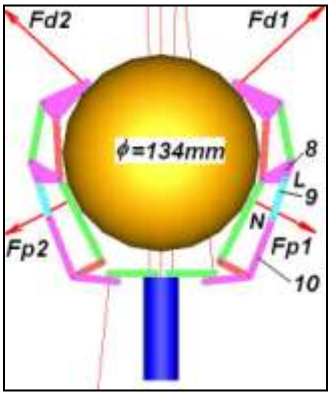

Figure 4. Grasping sequence with self-locking of distal phalanx.

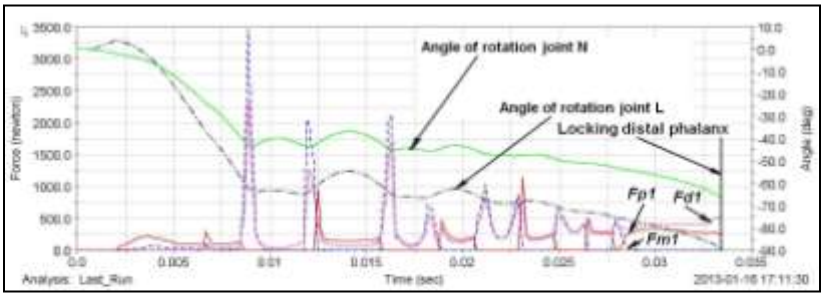

Figure 5. Variation of contact forces of a finger and rotation angles of couplings ***N*** and ***L,*** with self-locking of distal phalanx.

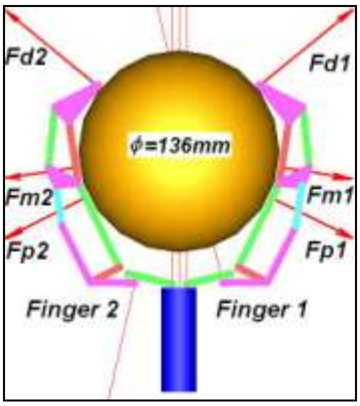

Figure 6. Configuration of contact forces on the 3 phalanxes of a finger, without self-locking of distal phalanx.

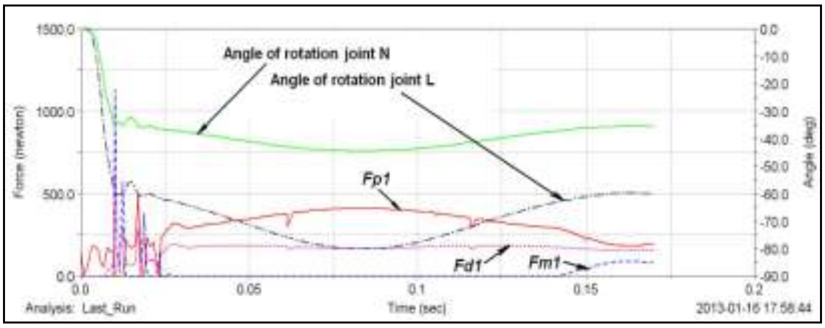

Figure 7. Variation of contact forces and rotation angles of couplings ***N*** and ***L,*** without self-locking distal phalanx.

By simulation with MSC ADAMS of the mechanical hand with two opposite fingers, (figure 4), (part I), elements 8, 9, 10 which are encompassed in couplings ***N*** and ***L*** are in extension only for diameters of the grasped object comprised between 126 mm and 134 mm; In figure 4 is presented a grasping sequence which observes this condition. The disadvantage of this type of grasping is that contact forces which ensure grasp stability are performed only in 4 points instead of 6 points, (on proximal and distal phalanxes). In figure 5 is presented, for a finger, the variation of respective contact forces and rotation angles of couplings ***N*** and ***L,*** for a simulation cycle. For the rotation angle in coupling ***N*** not to be higher than 65^o, the proximal phalanx has been fitted with a mechanical limit stop, and the chain drive has been fitted with a hydraulic system for compensation of efforts between fingers. The closing sequence can be finished with development of contact forces on all the three 3 phalanxes only for diameters of the grasped object, comprised between 134 mm and 140 mm. The disadvantage of this type of grasp is that, although is stable in 6 points, does not ensure the self-locking of distal phalanx, (figure 6). In figure 7 is presented, for one finger, the variation of the respective contact forces and rotation angle of couplings ***N*** and ***L,*** for one simulation cycle. Thus, it can be find out that upon finalization of grasping cycle, there exist contact forces with the object on each phalanx and these are comprised between 50 N and 120 N.

5. CONCLUSIONS

Following the interpretation of the results of simulation with MSC ADAMS, the following conclusions are drawn:

1. Ejection of the object under the distal phalanx is influenced by its diameter and its coordinates of disposition towards the middle phalanx;
2. Distal phalanx is responsible for the finalization of grasp and stops the expulsion process generated by the proximal phalanx;
3. Self-locking of distal phalanx takes place only for diameters of objects comprised between Ø = 126 ÷ 134 mm;
4. Upon self-locking of distal phalanx are not carried out contact isotropic forces/finger;
5. Finalisation of grasp by performance of contact isotropic forces/finger is carried out only for Ø = 134 ÷ 140 mm, but without being met the condition of self-locking of distal phalanx.

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