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Simulation of a Pneumatically Driven Robotic Gripper Used for Handling Cylindrical Workpieces

Calin-Octavian Miclosina, Mariana-Aliteia Gogoneata, Zoltan-Iosif Korka, Vasile Cojocaru

The paper presents the geometrical model of a robotic gripper with 3 fingers, accomplished by using SolidWorks software, used for grasping cylindrical workpieces of the same length, but with different diameters. Applying an action force to the gripper's pneumatic cylinder piston, for a certain cylindrical workpiece, the contact forces between the gripper and the workpiece are determined in the SolidWorks Motion module. Also, in the same module, a study by finite element method is accomplished in order to obtain the highest value of von Mises stress that occurs within the gripper's finger. This value is compared to the yield strength value of finger's material, for the verification of its structural integrity in operation.

Keywords*: modeling, simulation, robotic gripper, pneumatic driving, SolidWorks.*

1. Introduction

Nowadays robots are commonly found in various industrial and service applications [2], [5], [6], [7], [12].

The robotic grippers usually have 2 or 3 fingers, rigid or articulated [2], [3], [4], [5], [8], [10], [11].

Pneumatic driving is widely used for robotic grippers, due to its main advantages: relatively high speed, low investment and maintenance costs, elasticity provided by the air as the energy carrier, etc. However, disadvantages of pneumatic driving must be reviewed: low specific power, relatively low forces, the air exhaust produces noise, etc. [1], [2], [3], [5], [8], [9], [10].

The paper presents the simulation of gripper operation. Thus, an action force, determined by the air pressure, is applied on the pneumatic motor piston; the piston transmits the motion, and the force implicitely, to the articulated fingers which grasp the workpiece.

2. Robotic Gripper Model

The model of robotic gripper, accomplished with SolidWorks software, is shown in fig. 1. The piston rod (2) of the pneumatic cylinder (1) transmits the motion, through the connecting rods (3), to the fingers (4), which grasp the workpiece.

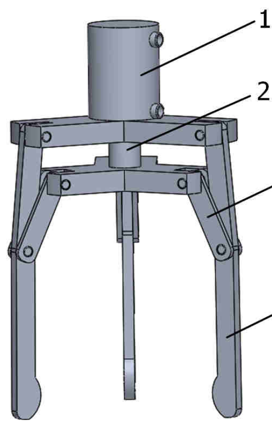
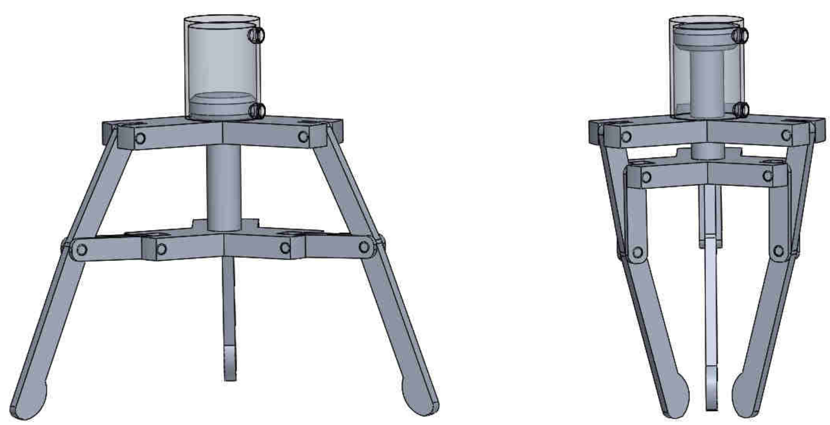


Figure 1. The model of robotic gripper.

The material of the gripper components is considered an aluminum alloy, 6061 Alloy, chosen from the SolidWorks materials library.

Figure 2 shows the model of the robotic gripper in 2 positions, open and close, determined by the piston’s stroke value.

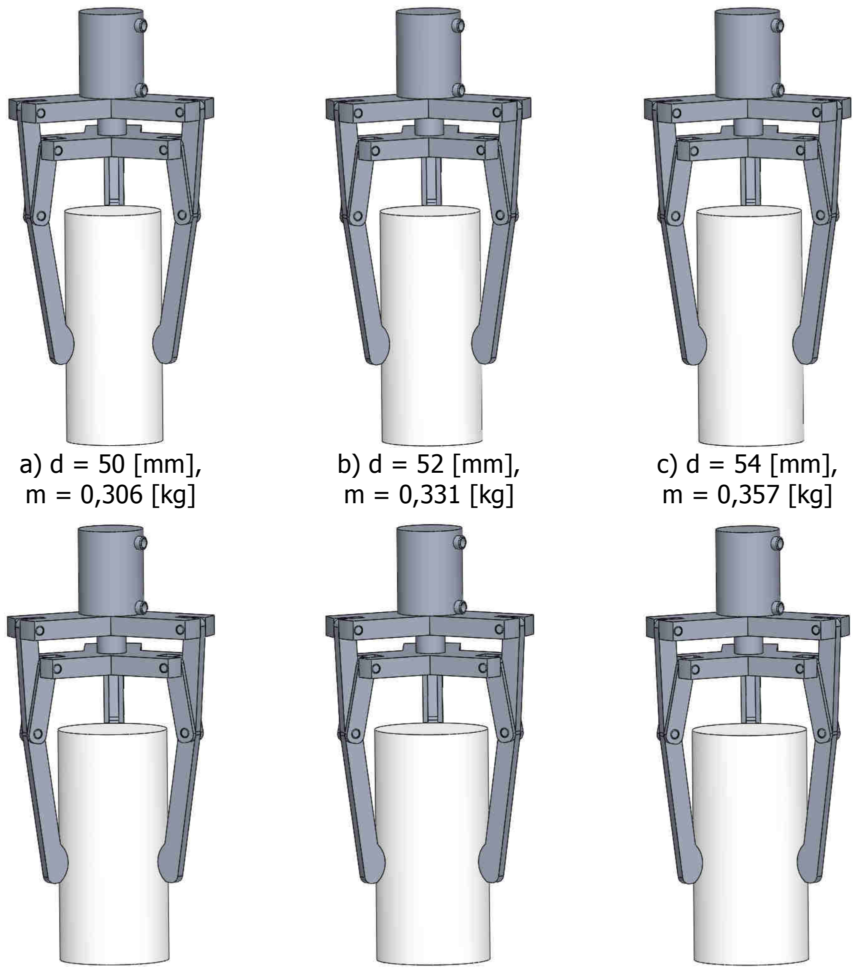


a) Open b) Close

Figure 2. Positions of the robotic gripper model.

3. Simulation of Grasping Operation

Cylindrical workpieces of the same length, 120 [mm], but with different diameters are considered to be grasped by the gripper, as shown in figure 3. The masses of the workpieces are indicated in the figure, considering the material of the workpiece PVC Rigid, chosen from the SolidWorks materials library.



a) d = 50 [mm], m = 0,306 [kg]

b) d = 52 [mm], m = 0,331 [kg]

c) d = 54 [mm], m = 0,357 [kg]

d) d = 56 [mm], m = 0,384 [kg]

e) d = 58 [mm], m = 0,412 [kg]

f) d = 60 [mm], m = 0,441 [kg]

Figure 3. Cylindrical workpieces of the same length, but with different diameters, grasped by the gripper.

In order to grasp the workpiece, the air, at a the pressure p = 4,5 [bar] = 0,45 [MPa], is introduced in the gripper's pneumatic cylinder, as shown in figure 4.

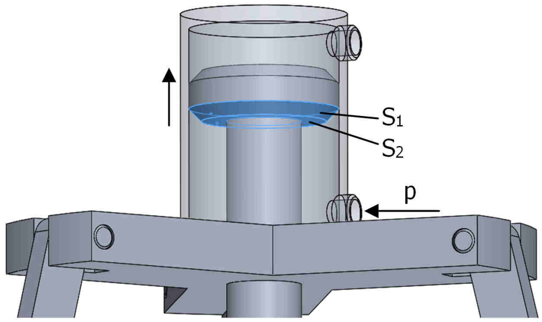


Figure 4. Gripper's pneumatic cylinder.

The pressure acts on the piston's surface marked in blue (figure 4); the value of the surface is computed by the SolidWorks software:

$$S = S_1 + S_2 = 305{,}45 + 314{,}16 = 619{,}\ 61\ [mm^2] \quad (1)$$

For the given pressure, the corresponding action force is given by the relation:

$$F = p \cdot S = 0{,}45 \cdot 619{,}61 = 278{,}82\ [N] \quad (2)$$

The most disadvantageous case is considered in simulation, namely the grasping of the workpiece with the higher dimensions and mass, corresponding to the case in figure 3, f.

The pressure can be applied in SolidWorks structural studies. In a SolidWorks motion study, the action force is applied on the piston, as presented in figure 5.

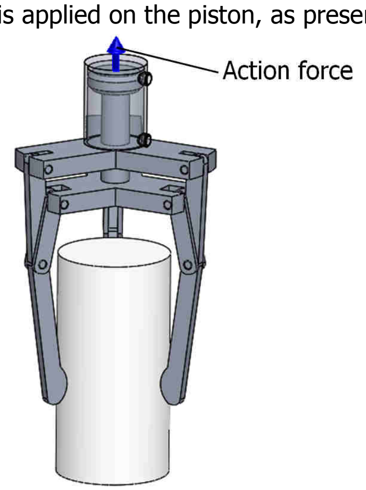
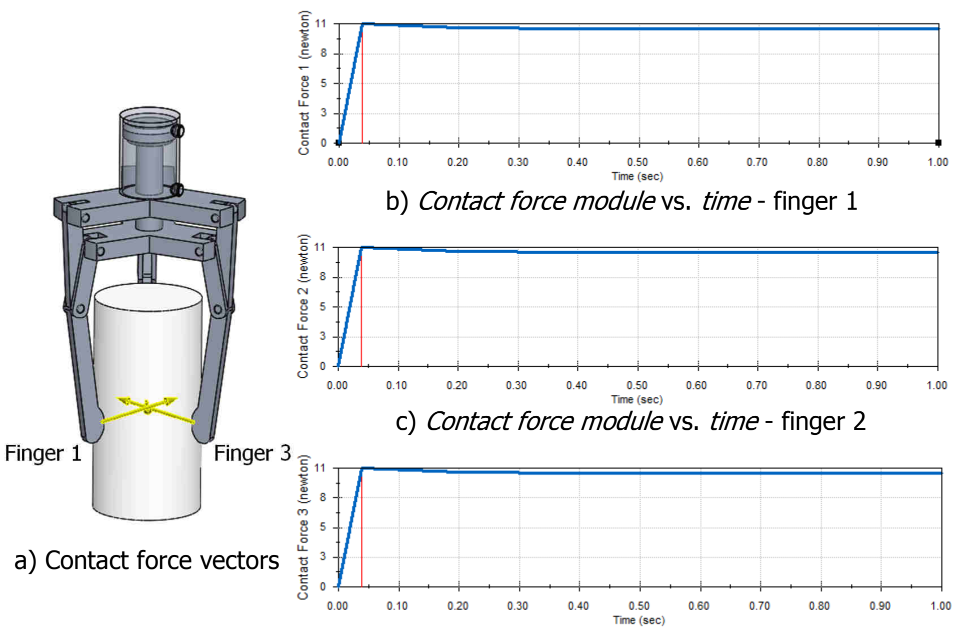


Figure 5. The action force applied on the piston.

The gravitational acceleration, with the value of 9806,65mm/s^2, is set for the simulation.

Solid body contacts are defined between the fingers and the workpiece, taking into account the materials they are modeled of.

After running the simulation, the SolidWorks software gives the possibility of determining the contact forces between the components where the contacts were defined, as presented in figure 6.



a) Contact force vectors

b) *Contact force module* vs. *time* - finger 1

c) *Contact force module* vs. *time* - finger 2

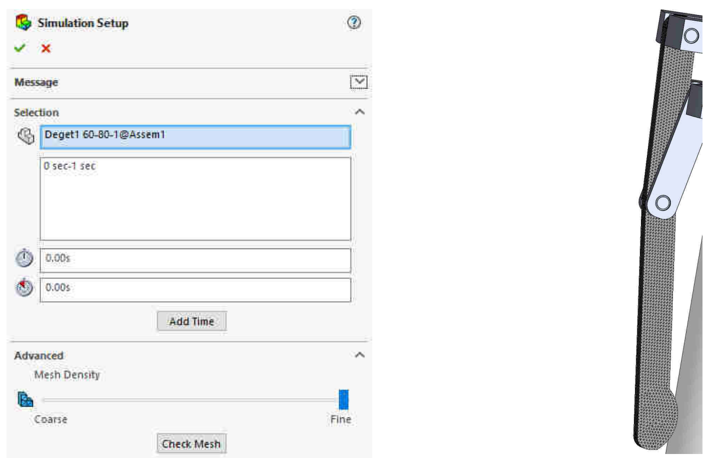
d) *Contact force module* vs. *time* - finger 3

Figure 6. Determination of contact forces between gripper fingers and workpiece.

It can be observed that the contact force module is stabilized around the value of 10 [N] for every finger.

4. Finite Element Analysis

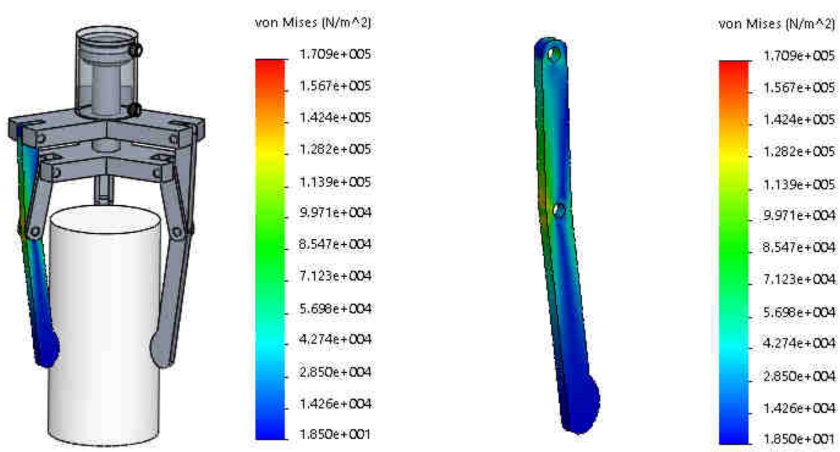
In the SolidWorks Motion module, a finger is selected and discretized in finite elements using the fine mesh density option, as shown in figure 7, a. The meshed finger is presented in figure 7, b.



a) Fine mesh density option b) Meshed finger

Figure 7. Finite element analysis setup.

For the selected finger, a finite element analysis is performed using the Simulation option in the SolidWorks motion study. The result is shown in figure 8.



a) The finger in the gripper assembly b) The finger visualized separately

Figure 8. Coloured map of von Mises stress.

5. Conclusions

On the basis of the robotic gripper simulation, the following conclusions can be drawn:

- the contact forces between fingers and workpiece have relatively low values, but enough to ensure the grasp of the workpiece;

- the fingers develop the same contact force, due to mechanism symmetry;

- the maximum value of von Mises stress, $1{,}709 \cdot 10^5$ [N/m^2] = 0,1709 [N/mm^2], is much smaller than the value of material's yield limit, 55,1485 [N/mm^2]; there is no danger for the finger to break.

For further research:

- the lengths of the gripper links can be modified, for the increase in the grasping force in the conditions of maintaining the same air pressure in the pneumatic cylinder;

- the shape and the thickness of the finger can be optimized in order to save material.

References

[1] Catrina C., *Pneumatic Driving in Material Handling Systems*. Recent, vol. 15, no. 3 (43) November 2014, 155-159.

[2] Ceccarelli M., *Fundamentals of Mechanics of Robotic Manipulation*. Springer Science+Business Media Dordrecht, 2004.

[3] Gogoneata M.-A., *Proiectarea unui dispozitiv de prehensiune al unui robot industrial pentru manipularea pieselor având forme şi dimensiuni diferite*, Bachelor degree thesis, scientifical coordinator Miclosina C.-O., „Eftimie Murgu" University of Resita, 2017.

[4] Miclosina C., Vela I., Gillich G.R., Amariei D., Vela D., *On the Use of Robotic Grippers with Shape Memory Alloy Actuators in Handling Light-Weight Workpieces*. Annals of DAAAM for 2007 & Proceedings of the 18th International DAAAM Symposium "Intelligent Manufacturing&Automation: Focus on Creativity, Responsibility, and Ethics of Engineers", 2007, 451-452.

[5] Miclosina C.-O., *Roboti industriali si linii flexibile,* Editura Eftimie Murgu, Resita, 2009.

[6] Miclosina C.-O., Campian C.V., *3D Modeling and Motion Simulation of the Guiding Device of a Parallel Topology Robot*, Robotica& Management, Vol. 15, No. 2, 2010.

[7] Miclosina C.-O., Cojocaru V., Korka Z.-I., *Dynamic Simulation of a Parallel Topology Robot Operation*, ROBOTICS 2014 – VIth International

Conference on Robotics, October 23-25, 2014, Bucharest, Romania, published in Applied Mechanics and Materials, Vol. 762, 2015, 107-112.
[8] Monkman G.J., Hesse S., Steinman R., Schunk H., *Robot Grippers*. Wiley-VCH, Weinheim, 2007.
[9] Stacey C., *Practical Pneumatics*. Routledge, 2015.
[10] Staretu I., *Gripping Systems*. Derc Publishing House, Tewksbury, Massachusetts, 2011.
[11] Staretu I., *Structural Synthesis, Analysis and Design of the Modular Antropomorphic Grippers for Industrial Robots*. 3rd International Conference "Research & Innovation in Engineering", COMAT 2014, 16-17 October 2014, Brasov, Romania, 86-91.
[12] Vela I., Miclosina C., Vela D.G., Cojocaru V., Amariei D., Bizau V., *Activities in Robotics Domain at „Eftimie Murgu" University of Resita*. Robotica & Management, Vol. 14, No. 2, December 2009, 33-35.

Addresses:

- Assoc.Prof.Dr.Eng. Calin-Octavian Miclosina, "Eftimie Murgu" University of Reşiţa, Traian Vuia Square, No. 1-4, 320085 Resita, c.miclosina@uem.ro
- Eng. Mariana-Aliteia Gogoneata, "Eftimie Murgu" University of Reşiţa, Traian Vuia Square, No. 1-4, 320085 Resita, mariana.gogoneata@student.uem.ro
- Lect. Dr. Eng. Zoltan-Iosif Korka, "Eftimie Murgu" University of Resita, Traian Vuia Square, No. 1-4, 320085 Resita, z.korka@uem.ro
- Lect. Dr. Eng. Vasile Cojocaru, "Eftimie Murgu" University of Resita, Traian Vuia Square, No. 1-4, 320085 Resita, v.cojocaru@uem.ro