BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 64 (68), Numărul 4, 2018
Secţia
CONSTRUCŢII DE MAŞINI

FINITE ELEMENT ANALYSIS IN DEVELOPING NEW SOLUTION OF GRIPPING SYSTEMS

BY

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Received: November 12, 2018
Accepted for publication: December 17, 2018

Abstract. The paper presents a new contribution to development of gripper design. Considering the solutions from specialized literature one consider an gripping system that is configurable and can be multitask. It has four fingers and two cylinders, with pneumatic drive. The primary cylinder will move the fingers in order to act like an standard gripper. The new element is the second cylinder which will drive the fingers in order to change the position, modifying the system from four to two fingers gripper, thus enhancing the objects type range. The solution is then validated by finite element analysis. From this analyze one can determine the maximum weight of the products that can be lifted with the help of this type of gripper.

Keywords: gripper; design; finite element; analyze.

1. Introduction

The gripping mechanisms aimed to realize gripping operations of objects in order to move, transfer or assembly. This operation is used in a robotised technological process (Khoo, 2008; Deaconescu, 2008; Rajput, 2008).

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The human hand can be replace by a gripping mechanism in a order to be effective in repetitive cycles and handle heavy objects. Also it can operate in extreme conditions and temperatures (Monkman and Hesse, 2007).

There can be numerous types of shapes and sizes for the parts that must be handled. It is almost impossible to design a gripper that is suitable for all parts. One can utilize electric motors or pneumatic cylinders in order to drive two fingers, those grippers are designed for one specific job. New technological developments could give new opportunity in order to develop universal gripping systems (Burak, 2010).

2. New Solution

A new gripping mechanism was designed considering four fingers, opening/closing parallel and pneumatic drive. Having in view the necessity of a new flexible gripper that can grab numerous types of parts, it was added a second cylinder together with a linkage system that could lead to the change of the fingers configuration, thus, transforming the gripper mechanism from four fingers to a two fingers.

In Fig. 1 one present the kinematic scheme of the system that was designed.

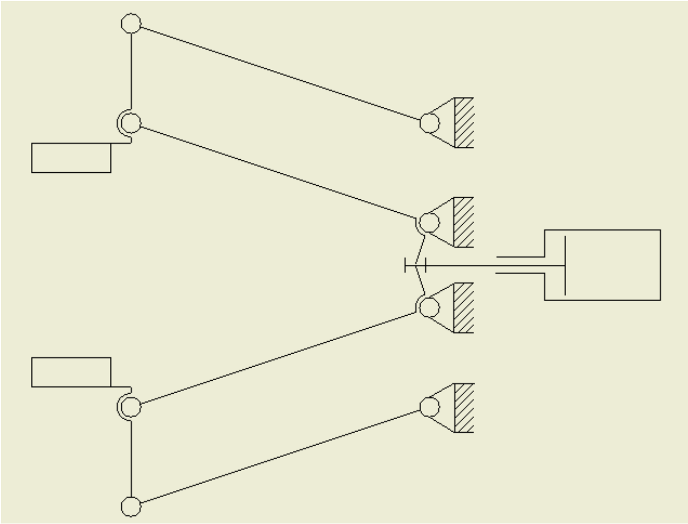


Fig. 1 – Kinematic scheme.

In Fig. 2 is the designed the four fingers gripper system.

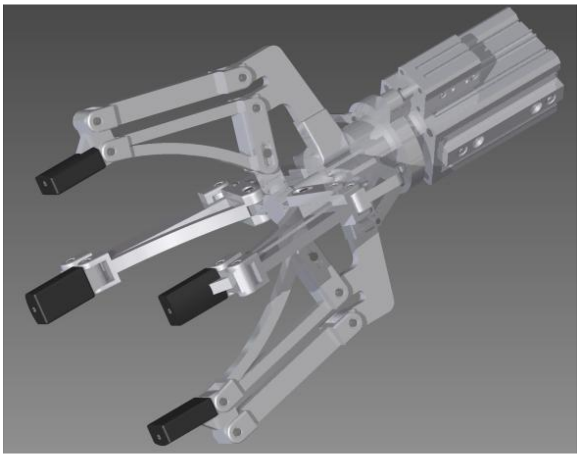


Fig. 2 – The design of four fingers gripper system.

The operating principle of the main cylinder is described in the Fig. 3.

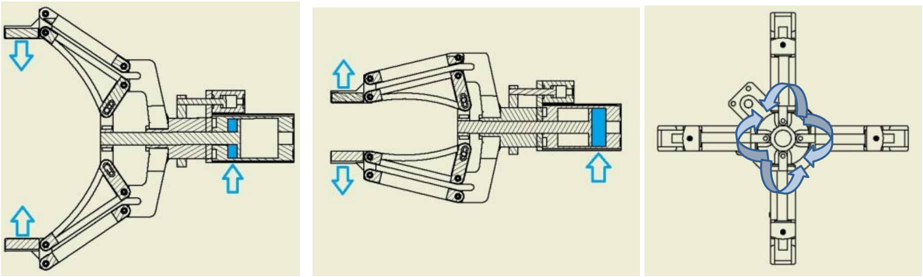


Fig. 3 – Main cylinder operating principle.

The final result after acting the second cylinder and the system transformation in two fingers gripper is represented in Fig. 4.

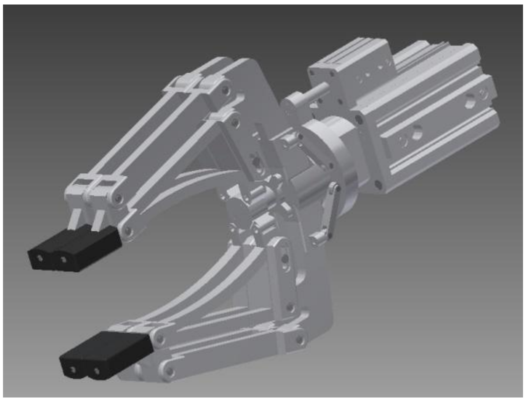


Fig. 4 – Two finger gripper.

In Fig. 5 one present several types of products that can be manipulated by the gripper.

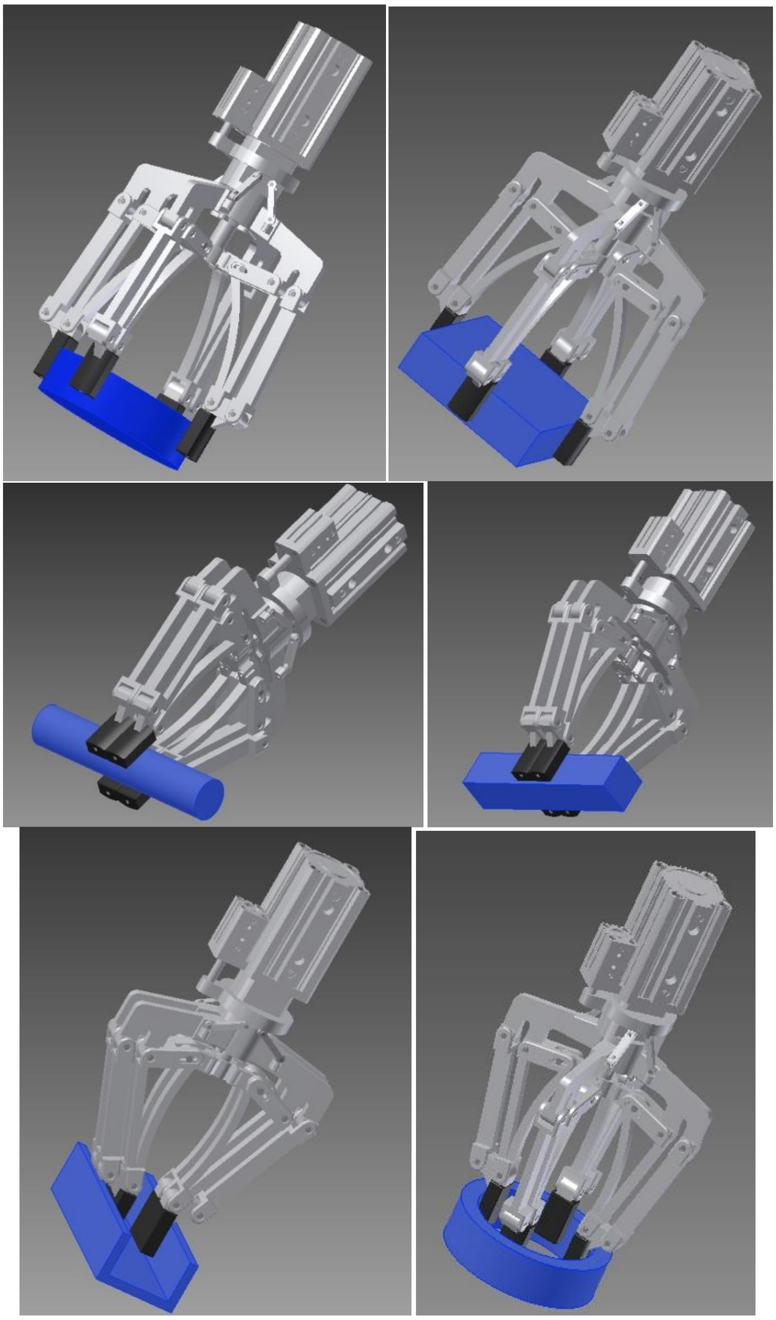
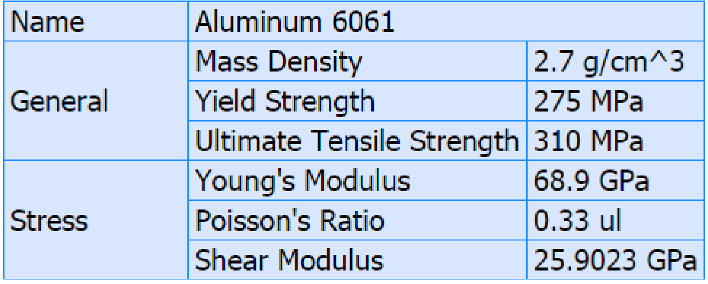


Fig. 5 – Types of workpiece manipulated with the help of gripper.

3. Finite Element Model

For the construction of the prehensive system one utilise the Aluminium 6061 widely used for the grippers, mainly for. The mechanical properties of this type of material are presented in Table 1.

Table 1
Mechanical Properties of Aluminium 6061



Name	Aluminum 6061	
General	Mass Density	2.7 g/cm^3
	Yield Strength	275 MPa
	Ultimate Tensile Strength	310 MPa
Stress	Young's Modulus	68.9 GPa
	Poisson's Ratio	0.33 ul
	Shear Modulus	25.9023 GPa

For all other parts used in the griper construction one consider carbon steel (Table 2).

Table 2
Mechanical Properties of Steel

Name	Steel, Carbon	
General	Mass Density	7.85 g/cm^3
	Yield Strength	350 MPa
	Ultimate Tensile Strength	420 MPa
Stress	Young's Modulus	200 GPa
	Poisson's Ratio	0.29 ul
	Shear Modulus	77.5194 GPa

The boundary constraints are presented in the Fig. 6.

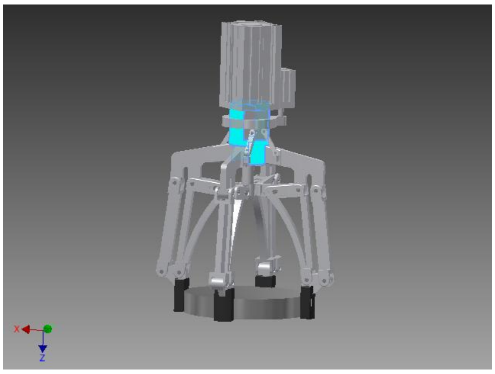


Fig. 6 – Fixed boundary constraints.

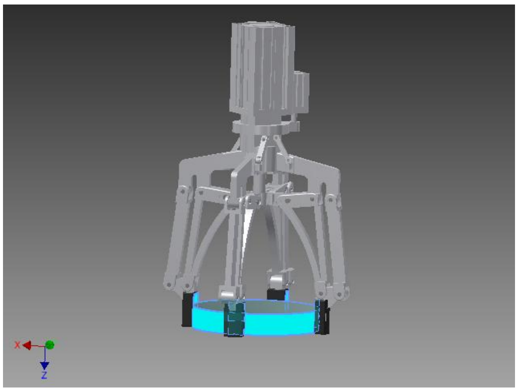
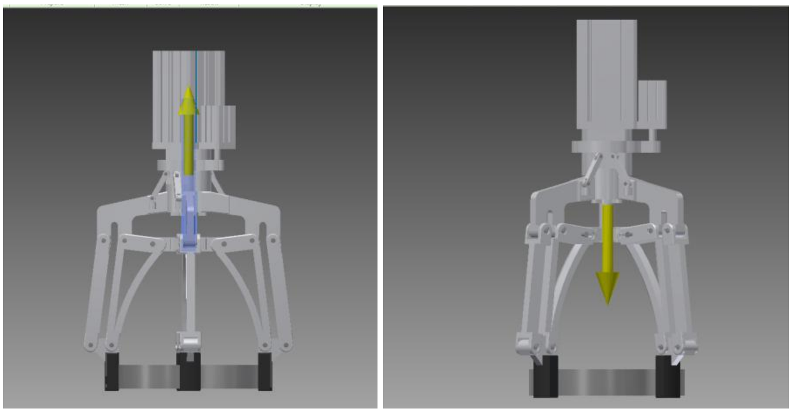


Fig. 7 – Friction type constraints.

In Fig. 7 one presents the location of the friction type constraints.

In Fig. 8 it is presented the way the force is applied in the system. The used force value is 2800 N.



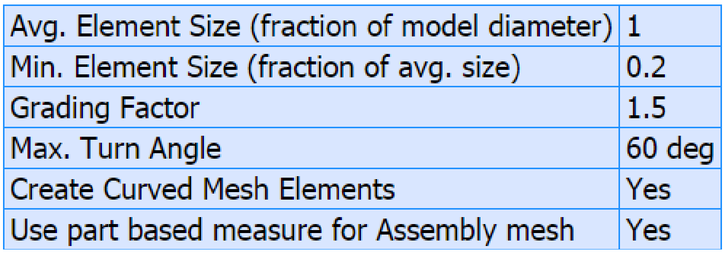
a *b*

Fig. 8 – Force system: a) hydraulic force; b) gravitational force.

In the Table 3 it is presented the data used in meshing the assembly.

Table 3

Mesh Data



Avg. Element Size (fraction of model diameter)	1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes
Use part based measure for Assembly mesh	Yes

In Fig. 9 it is presented the meshed model. The meshing is done using tetrahedral finite element.

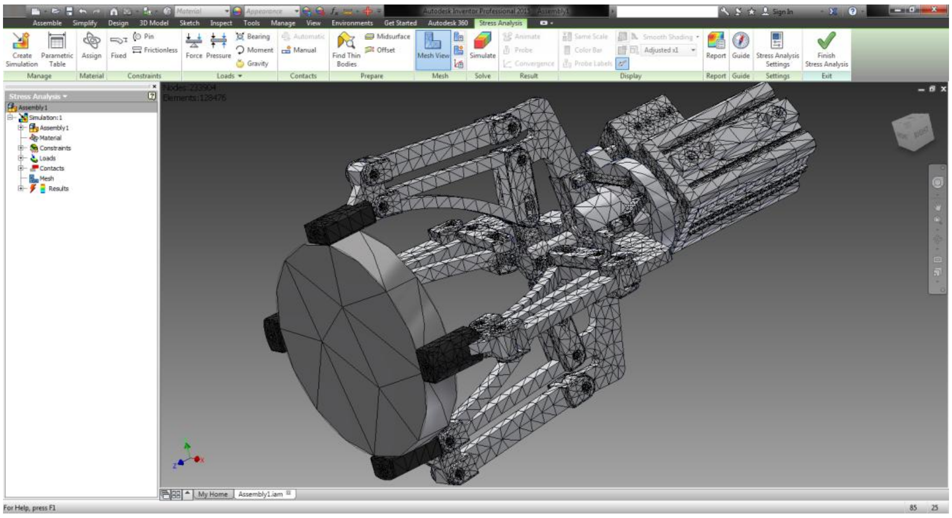


Fig. 9 – Meshed Model.

4. Results

In the following it is presented the results of the finite element analysis for the gripper used in the above mentioned conditions. In Fig. 10 it is presented the distribution of the Von Mises stress.

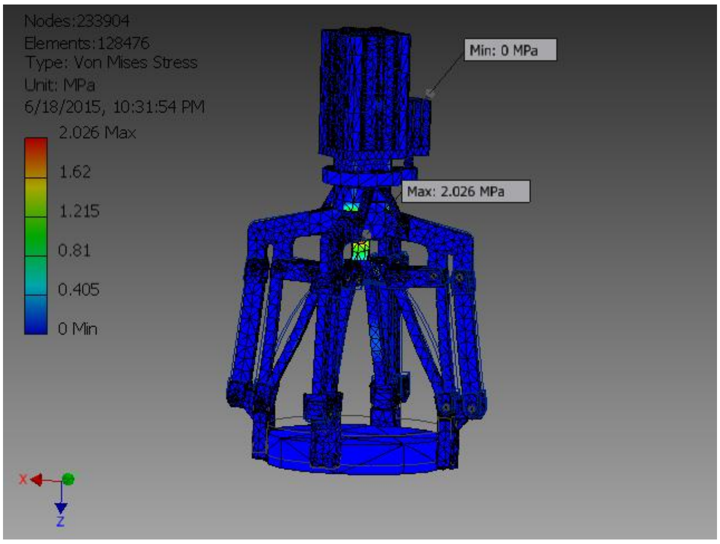


Fig. 10 – Von Mises stress.

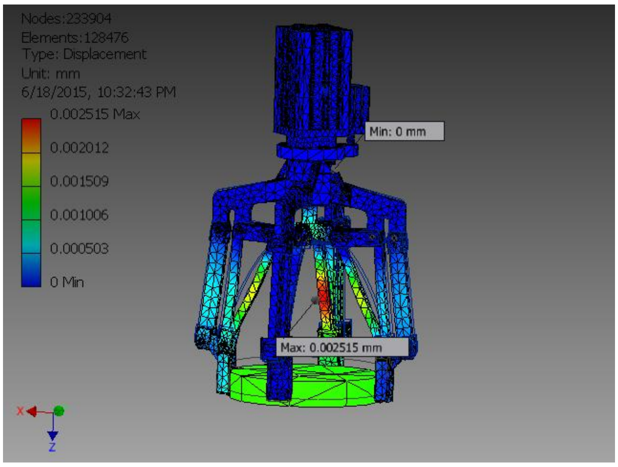


Fig. 11 – Displacements.

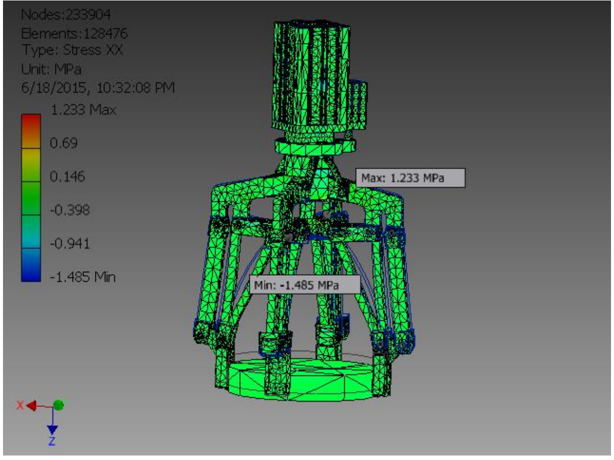


Fig. 12 – Normal stress σ_x.

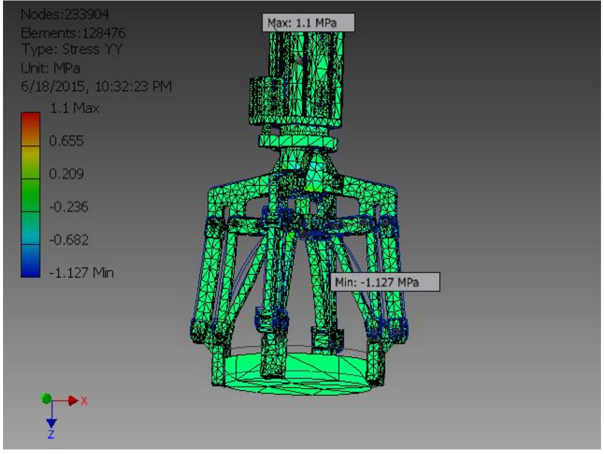


Fig. 13 – Normal stress σ_y.

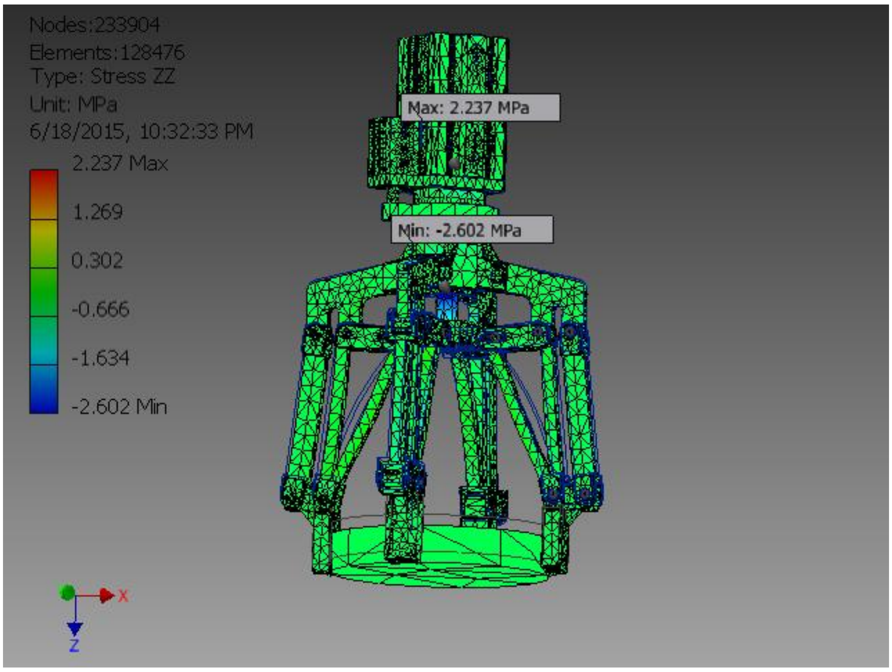


Fig. 14 – Normal stress σ_z.

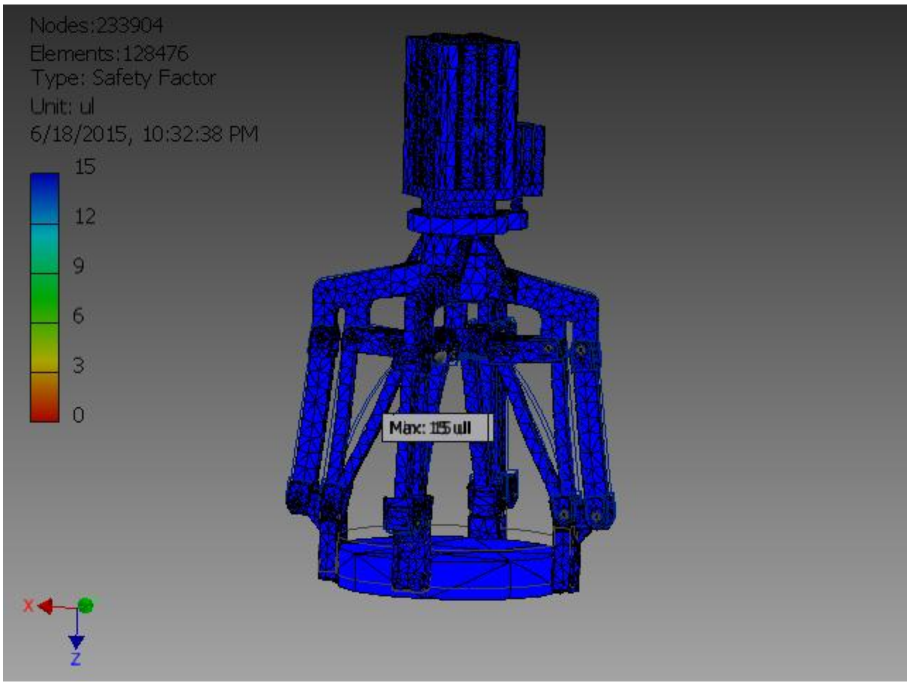
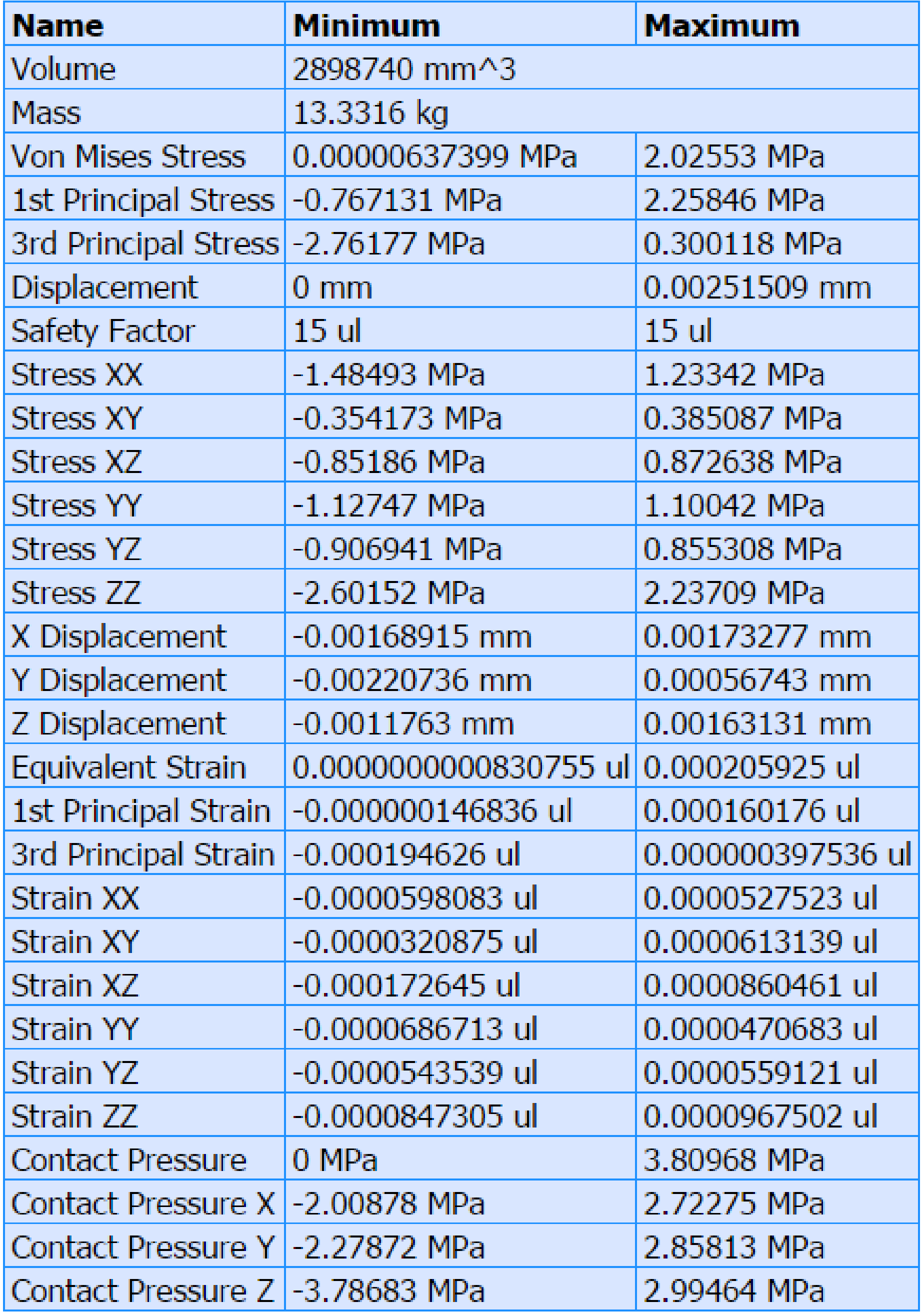


Fig. 15 – Safety Factor.

In the Table 4 it is presented the minimum and maximum values.

Table 4
Values Determined Using Finite Element Analysis



Name	**Minimum**	**Maximum**
Volume	2898740 mm^3	
Mass	13.3316 kg	
Von Mises Stress	0.00000637399 MPa	2.02553 MPa
1st Principal Stress	-0.767131 MPa	2.25846 MPa
3rd Principal Stress	-2.76177 MPa	0.300118 MPa
Displacement	0 mm	0.00251509 mm
Safety Factor	15 ul	15 ul
Stress XX	-1.48493 MPa	1.23342 MPa
Stress XY	-0.354173 MPa	0.385087 MPa
Stress XZ	-0.85186 MPa	0.872638 MPa
Stress YY	-1.12747 MPa	1.10042 MPa
Stress YZ	-0.906941 MPa	0.855308 MPa
Stress ZZ	-2.60152 MPa	2.23709 MPa
X Displacement	-0.00168915 mm	0.00173277 mm
Y Displacement	-0.00220736 mm	0.00056743 mm
Z Displacement	-0.0011763 mm	0.00163131 mm
Equivalent Strain	0.0000000000830755 ul	0.000205925 ul
1st Principal Strain	-0.000000146836 ul	0.000160176 ul
3rd Principal Strain	-0.000194626 ul	0.000000397536 ul
Strain XX	-0.0000598083 ul	0.0000527523 ul
Strain XY	-0.0000320875 ul	0.0000613139 ul
Strain XZ	-0.000172645 ul	0.0000860461 ul
Strain YY	-0.0000686713 ul	0.0000470683 ul
Strain YZ	-0.0000543539 ul	0.0000559121 ul
Strain ZZ	-0.0000847305 ul	0.0000967502 ul
Contact Pressure	0 MPa	3.80968 MPa
Contact Pressure X	-2.00878 MPa	2.72275 MPa
Contact Pressure Y	-2.27872 MPa	2.85813 MPa
Contact Pressure Z	-3.78683 MPa	2.99464 MPa

5. Conclusions

The contribution to this work has been researching and finding an optimal solution for a prototype system of prehensive that meets as many conditions as possible from the current market requirements in the field of industrial robots.

As a result of the research, we have concluded that a four-finger prehensive system has a large number of advantages, the most important being the self-centering of the piece between the fingers of the prehensor providing a high degree of precision for the positioning of the objects and a high degree of safety due to the large number of contacts between the piece and the fingers of the system. But this four-finger prehensive system is problematic when it comes to long bar-shaped parts. The most suitable for this type of parts is the two-finger prehensive system. Taking into account the above, we designed and designed a flexible flexing system in the virtual environment that can change its fingers configuration, being able to operate with both fingers and two fingers grouping two by two. This group has the advantage that the contact surface remains large enough to provide a tightening safety of the object to be handled.

From the research we have concluded that a prehensive system with parallel opening is preferable to the angular ones because it offers the same contact surface between the fingers and the piece regardless of the size of the part, the sliding of the part being minimal. Taking into account these, we also adopted the system designed this kind of opening of the play.

The development trend in the field of pneumatic drives has led to low manufacturing costs, develops very large forces, is compact, light and does not pollute the environment. This has led me to choose a pneumatic actuator.

Once the prehensive system was designed, we performed a finite element analysis in order to determine the maximum weight that can be manipulated with it. In this calculation we took into account the maximum power that can be developed by the pneumatic drive, the dimensions of the prehensive system, the gravity acceleration and the throttle acceleration, which has a major impact on the final weight. As a result of these calculations we found out that the maximum weight that can be handled is 11.9 kg.

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ANALIZA CU ELEMENTE FINITE A UNUI SISTEM TIP GRIPPER UTILIZAT ÎN CONSTRUCȚIA UNUI BRAȚ ROBOTIC

(Rezumat)

Lucrarea prezintă o contribuție la dezvoltarea în domeniul sistemelor de prehensiune și anume o nouă soluție de gripper. Pe baza studiilor efectuate a fost ales sistemul de prehensiune care este capabil să aibă mai multe configuraţii pentru realizarea unor sarcini multiple. Este proiectat considerând patru degete paralele și două cilindri pneumatici. Cilindrul primar acționează degetele pentru a prinde obiecte ca un dispozitiv de prindere obișnuit. Principala contribuție este introducerea celui de-al doilea cilindru care schimbă poziția degetelor, transformând sistemul dintr-un dispozitiv de prindere cu patru degete într-un dispozitiv de prindere cu două degete, prin aceasta extinzând posibilitatea prinderii unei game mai mari obiecte. Soluția este apoi validată prin analiza elementelor finite. Din această analiză se poate determina greutatea maximă a produselor care pot fi ridicate cu ajutorul acestui tip de gripper.