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CONSIDERATIONS ON THE DESIGNING AND MANUFACTURING OF THE GRIPPING ELEMENTS OF A GRIPPER WITH TWO ADJUSTABLE JAWS

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Abstract: *The paper brings original information in the field of gripping systems, regarding the design of simple and flexible devices easily adaptable to a wide range of practical applications. Aspects related to the constructive and functional design of the gripping elements of a gripper with two adjustable jaws are presented. It shows a comparative analysis for different sizes and shapes of the manipulated objects, having low masses. Also, a finite element analysis of the gripping components is done and their manufacturing process is presented. At the end, conclusions are drawn regarding the availability of the analyzed solutions and issues related to the improvement of the grippers.*

Key words: *Gripping system with two jaws, constructive design, finite element analysis*

1. INTRODUCTION

Gripping devices are used to move or transfer a component within a robotic technological process [1]. It is important that the gripping of the objects should not affect their integrity and their handling to the destination should take the shortest path, overcoming any obstacles and avoiding collisions.

In industrial applications, in most cases, the aim is to use gripping systems as simple and light as possible, for reasons of reliability and safety in operation, as well as economy. The use of the current grippers [2] is to handle metal parts of cylindrical/parallelepipedical shape, having between 40 and 100 mm in diameter/thickness and maximum 0.7 kg mass.

2. SUBJECT PRESENTATION

The analyzed application refers to the Electric 2-finger parallel gripper EGP 40-N-N-B (Fig.1). Fig.2 highlights the dimensions and its connection areas, 1 and 2, with the gripper.

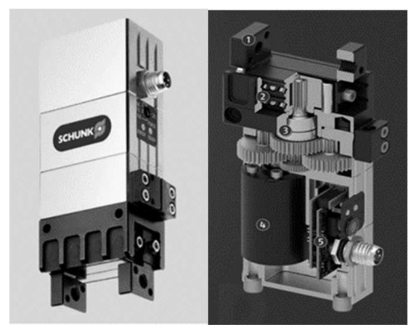

Fig. 1. SCHUNK-0310940 EGP 40NNB gripper
1- technological base of placement/fixing; 2- transversal guide system with rolls; 3- rack and pinion gear; 4- servomotor; 5- controller

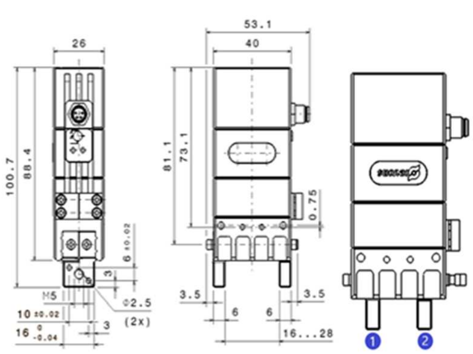

Fig. 2. Dimensional characteristics of the gripper

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The device designed within this work consists of two subassemblies, mounted on one of the bases 1 and 2 of the gripper. A component of bent steel strip will be attached to each of the two elements, intended to support the jaws that grip the handled objects.

3. DESIGNING THE COMPONENTS

The design described in the paper aims at obtaining gripping elements as simple and easily adaptable as possible, depending on the shape and dimensions of the handled objects. Also, their mounting and dismounting should be quick and easy, and the machining should be the usual one: milling, drilling, boring, on standard MUCN, in 3 axes.

The component shown in Fig. 3 was obtained using CATIA Generative Sheetmetal Design [3], preferred for the complex set of tools for design and introduction of functionalities.

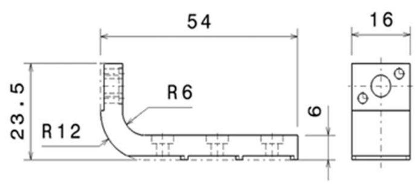

Fig. 3. Dimensional characteristics of the supporting component

The bent steel strip solution was preferred due to its lower mass as well as to convenience of semi-finished products and processing. The shape of the part, before and after parameterizing the length, is shown in Fig.4.

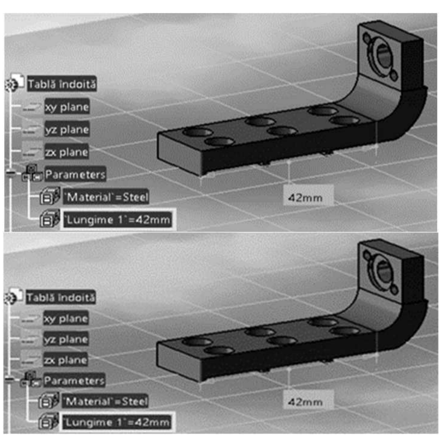

Fig. 4. Designing the bent steel strip component

OLC45 steel was chosen for the two components, semi-hard, non-alloy, easily workable and accessible. The components are centered and fixed on the surfaces of the gripper with two pins Φ2.5mm and a M5 screw, after the surface of the component was milled according to Fig. 5.

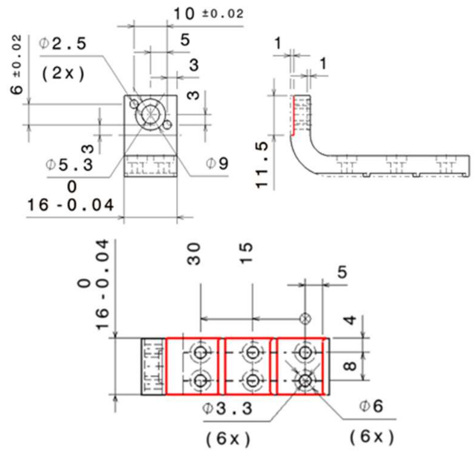

Fig. 5. Highlighting the milled areas, for mounting

The mounting of the two components on the body of the gripper is shown in Fig. 6.

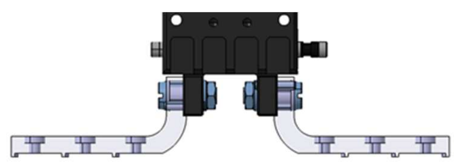

Fig. 6. Mounting the components on the gripper

The openings of the gripper, with the two extreme positions, are shown in Fig.7.

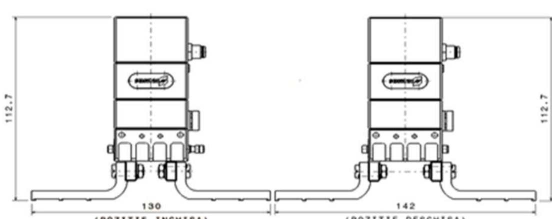

Fig. 7. Overall dimensions and opening of the supporting components

4. DESIGNING THE JAWS

The presented device being designed as a reconfigurable device, it involves the design of three pairs of jaws, each one having certain geometric features (Fig.8). The jaws are designed to grip light but bulky objects, cylindrical or parallelepipedal. As in the case of the bent steel strip, the jaws were designed parametrically, so that their shapes and dimensions could be easily modified in order to optimize them.

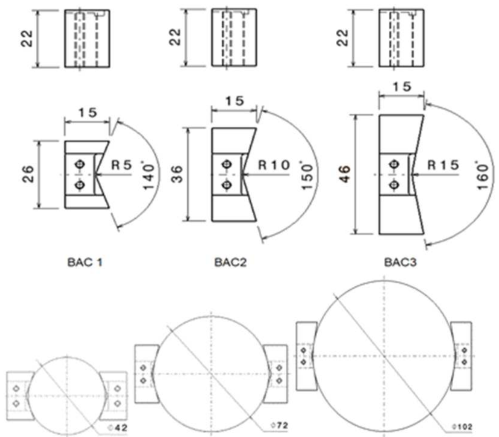

Fig. 8. The three types of jaws, shaped to grip cylindrical objects, diameters Φ42mm, Φ72mm and Φ102mm

In all three situations, the contact is made in a favorable manner, therefore the handling of this type of parts with the help of the designed device can be done successfully, as long as the whole assembly, together with the handled part, does not exceed the maximum mass the gripper can handle.

The material used for the jaws is a duralumin Al-Cu-Mg-Mn-Si-Fe.

The placement of the pairs of jaws for setting the contact with the surfaces of the handled parts is shown in Fig.9.

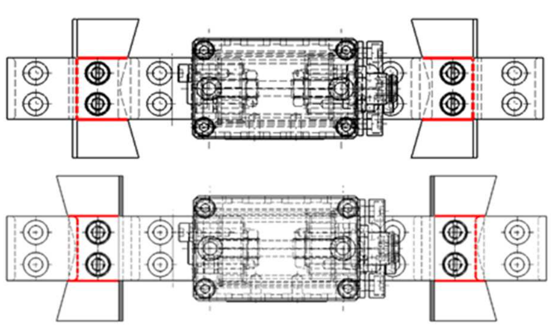

Fig. 9. Contact surfaces between the jaws and the two supporting elements

The pairs of jaws are attached to the bent components, in two variants of placement - depending on the shape of the handled parts, and at three different distances - depending on the size of the parts. This is shown in Fig.10, for the case of the smallest handled parts.

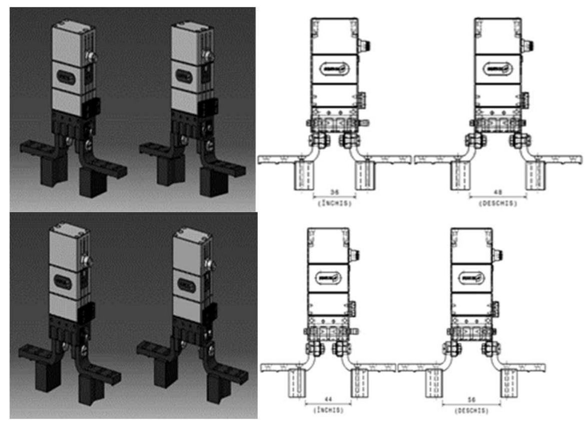

Fig. 10. Positioning the jaws for the smallest handled parts

To ensure proper centering between jaws and components, finishing milling is provided on the surfaces marked in Fig.5 and Fig.9.

5. FINITE ELEMENT ANALYSIS OF THE ELEMENTS SUPPORTING THE JAWS

A finite element analysis was performed [4], in which the appropriate constraints and the stress distributed on the concerned surfaces of the bent steel strips were established. In the present paper, assessing the masses of the component parts and mounting accessories of the device is important because it allows the assessment of the applied forces.

The physical characteristics of the device components, in the case of the smallest jaws, are presented in Fig. 11. Thus, the relevant masses are: steel strip m_p = 39g, jaws m_1 = 18g, m_2 = 26g, m_3 = 34g, the rubber elements applied on them for adhesion m_{c1} = 0.4914g, m_{c2} = 0 , 6916g, m_{c3} = 0.8918g as well as the aggregated masses of the assembly elements m_a = 14.1364g

Also, the mass of the SCHUNK-0310940 EGP 40-N-N-B gripper is considered known, Mp = 0.32 kg and the maximum loading mass, M = 0.7 kg.

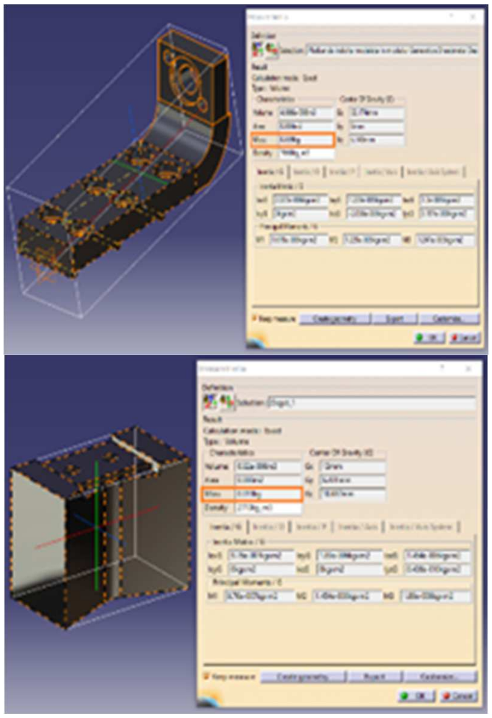

Fig. 11. The physical characteristics of the bent steel strip and the smallest jaw

The specific mass of the designed device was calculated, with the steel strips fixed, M_d = 88.1364g and in the variants with the three types of jaws attached, M_1 = 0.12 kg, M_2 = 0.14 kg, M_3 = 0.16 kg. In each of the three situations, the maximum mass of the handled objects is calculated, observing the loading limit M, resulting the following values: 570g, 554g and 538g.

Since the configuration of the device involves three pairs of jaws, mounted in three distinct areas (Fig.12), the distributed force of 4.5 N is applied in each of these areas of the bent steel strips.

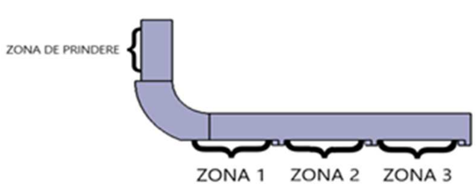

Fig. 12. The gripping area and the loading areas of the bent steel strips

Under the weight of the jaws and handled objects, the two bent components are subjected to bending. The constraints and distributed forces are applied, in turn, in each of the three areas of the steel strip. For zone 1, of minimum load, these are illustrated in Figure 13.

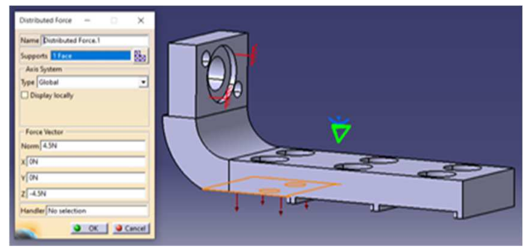

Fig. 13. Loading of the steel strip, in zone 1

The same procedure is followed for the other two loading areas. This analysis surveys the results related to deformations, stress and displacements, in all three areas. For zone 1, they are shown in Fig.14.

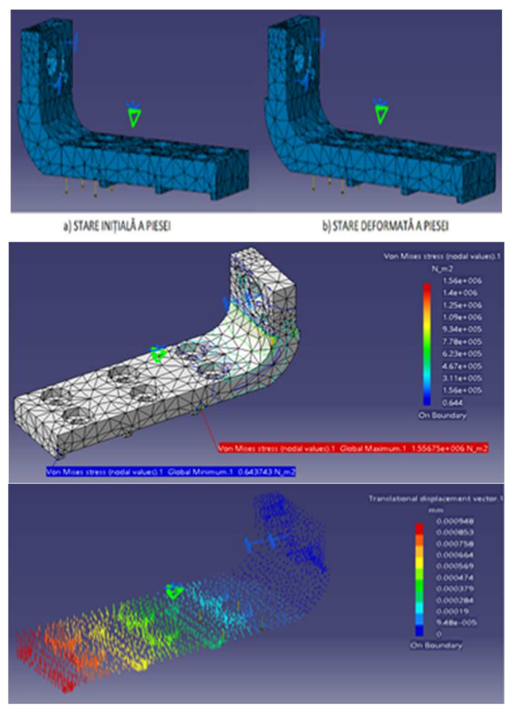

Fig. 14. Deformations, stress and displacements corresponding to zone 1

It is observed that at the distal extremity of the bent component, in case of maximum load (zone 3), the maximum stress reached 7.58MPa and the maximum displacements reach the value of 7.35µm. Analyzing the mechanical properties of OLC45 steel, it is noticed that the maximum limit of elasticity is much higher, so there are no residual deformations that affect the operation of the gripper.

A comparative analysis of the results obtained by applying FEA was performed in two cases: with linear and parabolic elements, respectively [4], as can be seen in Table 1. It is obvious that the values of maximum stress and deformations are higher in the second case.

Results of Finite Element Analysis *Table 1*

Comparative criteria	Analysis with linear elements			Analysis with parabolic elements		
	Zone 1	**Zone 2**	**Zone 3**	**Zone 1**	**Zone 2**	**Zone 3**
Maximum stress [N/m^2]	**$6{,}37\cdot 10^5$**	**$1{,}53\cdot 10^6$**	**$3{,}07\cdot 10^6$**	**$1{,}56\cdot 10^6$**	**$3{,}97\cdot 10^6$**	**$7{,}58\cdot 10^6$**
Minimum stress [N/m^2]	8,33	119	$1{,}26\cdot 10^4$	0,644	13,2	$6{,}44\cdot 10^3$
Maximum deformation [mm]	**$5{,}84\cdot 10^{-4}$**	**$22{,}1\cdot 10^{-4}$**	**$43\cdot 10^{-4}$**	**$9{,}48\cdot 10^{-4}$**	**$37{,}1\cdot 10^{-4}$**	**$73{,}5\cdot 10^{-4}$**
Minimum deformation [mm]	0	0	0	0	0	0
Coefficient of error [%]	49,5	49,8	50,4	19,7	16,6	15,6

6. DATA ABOUT THE MANUFACTURING PROCESS

A technological flow was established for manufacturing the bent component; the main operations are: bending, centering, cylindrical-frontal milling, drilling, borring, as shown in Fig.15a and Fig.15b. The metal cutting was done on CNC CM-1HAAS, in 3 axes, ideal for small parts [5].

Cutting regimes and operations were established using NX CAM software.

It results that the total time for processing the part is 7 minutes and 22 seconds, representing the actual cutting time.

In addition to this, more time is needed to make the part: time to carry out preparatory activities (studying the documentation, taking over the semi-finished products), time to start and adjust the MU, to fix and detach the part, to automatically change the cutting tools, to perform the control measurements, etc.

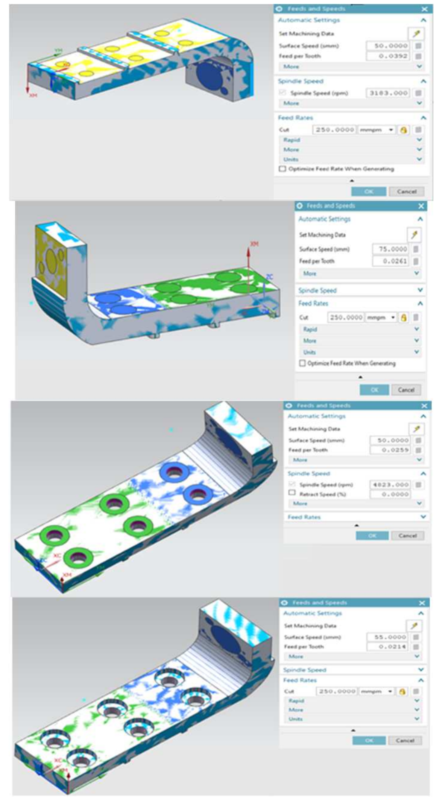

Fig. 15a Cutting in the area where the jaws are fixed

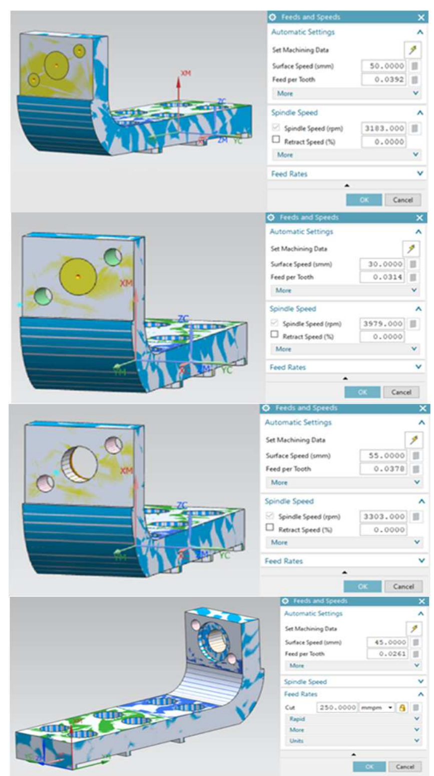

Fig. 15b Cutting in the area where the strip steel is fixed

7. CONCLUSIONS

Since the notion of gripping strategy is usually associated with the identification of ways to ease and optimize gripping processes, it can be considered that the device presented in this paper pursues such a potential strategy. The design of the device based on the use of three pairs of jaws has led to an increased efficiency, resulting in the possibility of handling parts of various sizes. The shape of the jaws and the possibility of mounting them in different positions was intended to obtain a structure that is easily adaptable, in order to handle parts of different shapes.

The maximum strain resulting from the application of finite element analysis is well below the limit of elasticity of the material chosen to manufacture the parts. The deformations recorded when applying the analysis are insignificant, as they do not have a residual character and do not influence the positioning accuracy of the gripper.

Both the two bent steel strips and their related jaws require simple processing, so the technologicity components of the device are good, involving relatively low costs.

The two bent steel strips are relatively long compared to the overall dimensions of the gripper body, but this is the feature that gives the device good adaptability and flexibility.

However, when using this device, the main drawback is the working space it requires, that must be large enough to avoid collisions with other elements in the operation area of the robot. This can be optimized in the future, through a more efficient adaptation of the shape of the steel strips or the use of interchangeable components.

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CONSIDERATII ASUPRA PROIECTARII SI PRELUCRARII ELEMENTELOR DE PRINDERE ALE UNUI PREHENSOR CU DOUA BACURI REGLABILE

Abstract. Lucrarea aduce contributii originale in domeniul sistemelor de prehensiune, in legatura cu proiectarea si prelucrarea unor dispozitive simple, flexibile si usor adaptabile la o gama larga de aplicatii practice. Sunt prezentate aspecte legate de proiectarea constructiva si functionala a elementelor de prindere ale unui prehensor cu doua bacuri reglabile, pentru situatia unor obiecte manipulate cu mase reduse. De asemenea, se realizeaza o analiza cu element finit a componentelor de prindere si se prezinta aspecte legate de fabricatia acestora. La final, se formuleaza concluzii cu privire la avantajele solutiilor analizate si eventuale imbunatatiri ce pot fi aduse prehensoarelor .

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