CONSTRUCTIVE OPTIMISATION OF A GRABBING DEVICE FOR ROBOTIZED HANDLING OF A AUTO BODY SHOP
Part II

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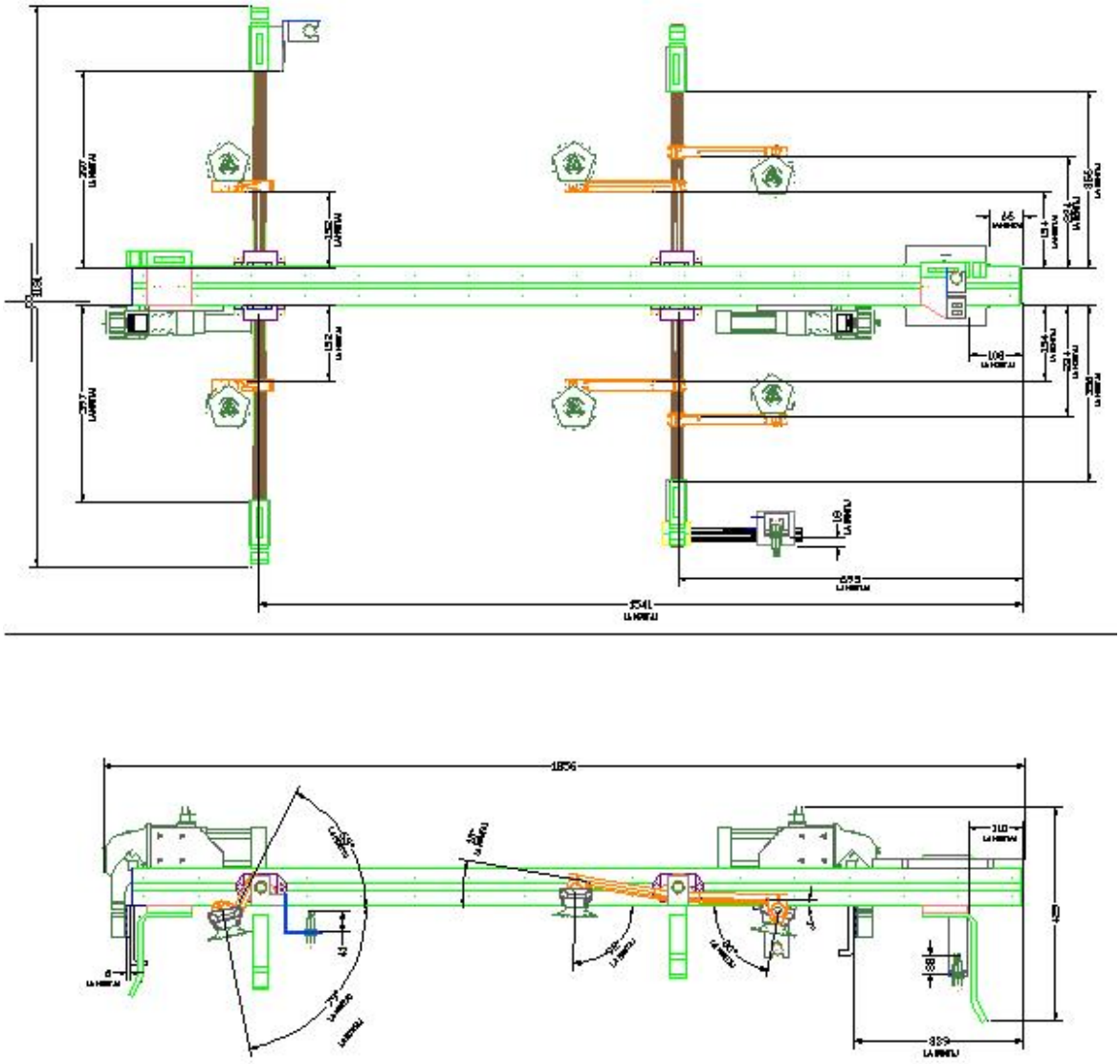
Abstract. This paper is based on a scientific research, made by the authors, with the aim to reduce the designing and execution time of a grabbing device, intended for the handling and transferring operation of a car body part. The grabbing device is designed and 3D shaped, presented in the paper, is realized by assembling typical elements of constructive types, the alignment and fixation of the handled object in the grabbing device being realised vacuum, pneumatically and mechanically.

1. Description and functionality of the designed vacuum grabbing device

The constructive type of the vacuum grabbing device modular assembly presented in the first part of the paper was projected by the authors with the aim of constructive and functionality optimization for a more efficient usage in the operations of grabbing, fixing and robotic handling of a metallic structure like a auto body rooftop. The Robotic handling has as aim the grabbing and transferring the metal structure, from one technological stage of manufacturing, such as cold compressing, technological operation made in a cambering/molding section, to another manufacturing point situated at a certain distance, where the handled object enters into a new phase of technological manufacturing.
This could be, for example, a department for thermo-chemical treatment, containing the stages for degreasing, cleaning-washing followed by a thermo-chemical treatment applied before the painting in electrostatic field of the handled element.
As we mentioned before, it can be observed from the 3D design of the assembly, that the component elements of the vacuum grabbing device designed are standardized and modulated, and because of this it allows a substantial reduction of the designing time and the reduction of the manufacturing time of the product. For this we had at our disposal, for documentation, catalogs from different companies devoted to this fields, from which we can name the companies TUNKERS, NORGREN, FESTO.
On a central aluminum extruded profile numbered 14, foreseen longitudinally with a T canal on each side, are assembled in order all the typical elements.
The first components installed are the two lateral devices for grabbing with claws, their clamps claws being pneumatically operated, and having the purpose of fixing and unfixing the auto body metallic structure, on the central area.
In picture 1 we can see a upper view of the vacuum grabbing device, and from this point of view we can observe the values of the linear and angular values of the mounting and associating contact, the composition, distribution and the adjustment of the main component elements by which it can be realized the centering, grabbing and fixing the auto body element, for the purpose of robotized handling.

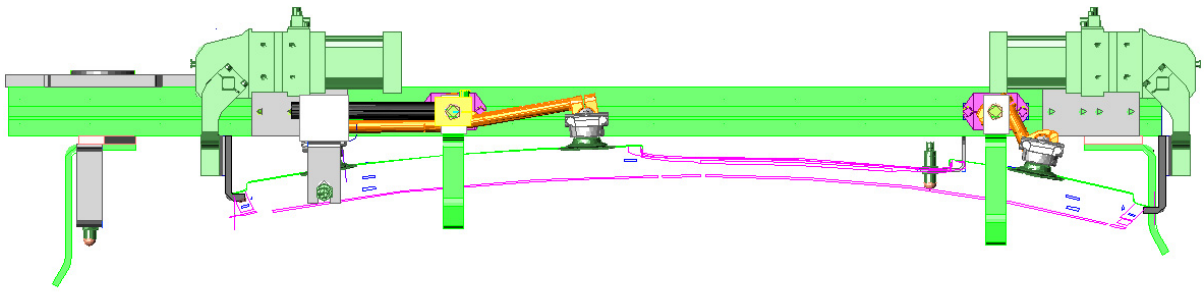


Picture 1. Upper view of the vacuum grabbing device assembly containing the adjustment rates of the principal elements of the assembly

Clamping the metallic structure is realized with the help of two clamping elements, claw type, named in the assembly clamping holder 10. These revolving elements make simultaneously, under the command of the pneumatically cylinder rod, a quick revolving movement at a 90^0 angle of the clamping holder. Both clamping holders are installed sideways, on the surface of the extruded section 14, with the help of some installation boards and some assembly elements with thread. The axial distance between the, is adjusted at installation, this adjustment being made according the dimension of the handled element situated in the grabbing zone. On two areas of the central extruded section 14, near the two constriction devices, are installed and fixed two pairs of tubular arms 24, 25, and at their end are installed, with the help of intermediary boards in the sensor support 6,7,8, the inductive supports 11, and at each tubular rod is installed a metallic guider 20,21.

On the two tubular rods situated near the coupling system of the robots board 1, with the coupling element of the robot, are installed, with the help of four mounting support 16, four

support arms 17, at which end being fixed four adjustable cup holders 18, and in these elements are mounted the four vacuum cups 19.
At the end of the other grabbing device, situated near the constriction system, on the two tubular rods, situated at a established distance, are installed another two vacuum cups. The linear and angular measures for installation and the adjustment rates of the measures, representing the longitudinal and transversal distances between the cups axis, the vacuum grabbing device has been presented on a 2D design of the assembly presented in picture 1.
In picture 2 we can see a front view of the 3D design of the vacuum grabbing device assembly, the view is presented below, and it presents the fixed object in the device in the grabbed position. The two grabbing claws, pneumatically operated, realizes the mechanical grabbing of the object, by simultaneous revolving their claws towards inside. As a result of this order it is realized the mechanical grabbing of the object, and all the cups, which are in composition of the vacuum grabbing device, simultaneously attach to the exterior flat surface of the car body element.



Picture 2. Front view of the 3D design of the assembly, the vacuum grabbing system in handling position with the grabbed object

From this picture we may observe the position of the cups in contact with the bent surface of the car body element, so that the cup axis will be perpendicularly on the bent surfaces which will be grabbed. The inductive sensors together with the detectors transmit the exact information's to the robot's driving system, so that the handled object can be centered and fixed by the grabbing device in optimum conditions.
The energetic connections with the compressed air network of the pneumatic cylinders and of the vacuum cups, is realized with different air circuits, which are fixed on the structure of the final grabber. The electric and informational connections are realized with electric cables, which contain different electric circuits, the interface being a quicker one by plugs.

2. Description of the running sequences while fixing and handling the object

After finishing the position adjustment of the two central grabbing devices, and for the six lateral cups, the vacuum grabbing device is installed to the coupling element of the handling industrial robot, regularly the ABB robot, and the connection being realized in the robot board 1. The robots interface is realized both from a mechanical and energetic point of view and from an informational one, too. In the operating system is introduced and memorized a computer software, which has been realized by a software programmer and based on its operations, the robot will execute the programmed operations.

Phase 1. The designed vacuum grabbing device with the two constriction systems with the claw support in the open position, is positioned over the sustaining support of the auto body roof top element. The five locators, composing the vacuum grabbing device, four sideways and one central, together with the 3 inductive sensors, assures the centering and the correct position of the locators over the grabbed element, transmitting all the necessary information's to the operating and running system of the robot.

Phase 2. In the moment of vacuum cups interaction with the plane surfaces of the object, with the help of the sensors it sees this position, in the fueling circuit it will be created a vacuum. All six cups realize in the first stage a vacuum grabbing of the car body rooftop.

Phase 3. The two sideway constriction devices pneumatically operated, receive simultaneously an operating command from a electromagnetic distributor type 5/3. As a result of the received command the pistons of the two pneumatic cylinder which compose the fixing typical systems, operates over the constriction support type claw, rotating them at 90^0, and so realizing the simultaneous fixing from sides and from a mechanical point of view, of the grabbed device.

Phase 4. The object auto body rooftop is fixed by the vacuum grabbing device and the robot continues the handling operation till he reaches in a new programmed position.

Phase 5. The object reached in the programmed position, after a command given by the operating system of the robot, will be released from the device.

Phase 6. The lateral claws of the grabbing device are opened simultaneously, releasing the object, which is still maintained in the fixed position by the vacuum force of those six cups. The robot will make a micro movement till the object will be sustained by the support, moment when the vacuum is interrupt, the vacuum cups releasing the object and puts it, slowly, at the programmed location, and afterwards the robot cycle is restarted.

3. Optimized running of the constriction pneumatic system of the device

The functional optimization is determined with the grabbing force relations developed according the compressed air pressure, used for the operation of the constriction system, and from the relations between the pressure force and cylinders rod diameter for auctioning the claw constriction system.

$$F_p = \frac{\pi \cdot D_m^2}{4} \cdot P_a = \frac{3.14 \cdot 64}{4} \cdot P_a = 50.24 \cdot P_a \qquad (1.)$$

La D_m =ct = 80 mm calculating are obtained the values from table 1

Table 1.

P_a [bar]	4	5	6	7	8	9	10
F_p [daN]	200,16	251,2	301,44	351,68	401,92	452,16	502,4

Based on the relation:

$$F_p = \frac{\pi \cdot D_m^2}{4} \cdot P_a \quad \text{[daN]} \qquad (2.)$$

considering P_a =10[bar] = ct.

Is determined the pressure force F_p

$$F_p = \frac{3.14 \cdot 10}{4} \cdot D_m^2 = 7.85 \cdot D_m^2 \qquad (3.)$$

Is made the table 2

Tabel 2.

D_m [cm]	5	6	7	8	9	10	12
F_p [daN]	196,25	282,6	384,65	502,4	635,85	698,74	1006

Based on the values presented in table 1 and 2, we can realize the constructive and functionality optimization of the constriction devices with claw elements, from the structure of the grabbing device, pneumatically operated.

For the pneumatic operation of the closing and opening systems the operation pressure is between (4-6) bar, the turning of the closing and opening system from 180^0-90^0 is 0,6 seconds.

4. Vacuum operation force calculus of the grabbing device

For a secure running of the projected vacuum grabbing device we made a succession of calculations, with the aim of precise determination of the fixing forces realized by the devices cups in contact with the plane surface of the auto body rooftop.
The used operation relations have as objective the determination of the minimum diameter of the devices cups (D), knowing the handled object weight, in our case the weight of the handled object is 120 kg, or determining by the calculus of the grabbing forces (F), knowing the dimensions of the cups.

$$F_i = A_S \cdot \Delta_p \ [N] \qquad (4.)$$

where: F_i – force developed by the cups

A_S – cups surface

Δ_p – un-pressure

For a number of cups is obtained: $I = \frac{\pi \cdot D^2}{4} \cdot n \cdot c \cdot \mu \cdot \Delta_p = m \cdot g \qquad (5.)$

where: D – cups diameter

n – cups number ; (n=6.)

c – security coefficient; ($c = 0{,}4 - 0{,}6$)

μ - friction coefficient;(μ = 0,14)

m – rooftop weight ; m = (120 Kg)

g – gravitational acceleration; g = (9,81)

$$D = \sqrt{\frac{4 \cdot m \cdot g \cdot 9{,}81}{\pi \cdot \Delta_p \cdot n \cdot c \cdot \mu}} \ [mm] \qquad (6.)$$

Using relation (6) we can determine the minimum diameter of the cup as it follows:

$$D_{\min} = \sqrt{\frac{4 \cdot 120 \cdot 9{,}81}{\pi \cdot 0{,}7 \cdot 6 \cdot 0{,}5 \cdot 0{,}14}} = \sqrt{\frac{4708}{0{,}92}} - = 71{,}53 \ mm$$

For security we will chose the constructive diameter of the cup $D = 85 \ mm$

From relation 4 we will obtain the force developed by a cup:

Δ_p – un-pressure = -0,7 daN/cm^2

$$A_S = \frac{3{,}14 \cdot 85^2}{4} = 5671{,}62\ mm^2$$

$$A_S = 56{,}71\ cm^2$$

$$F_i = 56{,}71 \cdot 0{,}7 = 39{,}69\ daN$$

$$F_i = 39{,}69\ daN$$

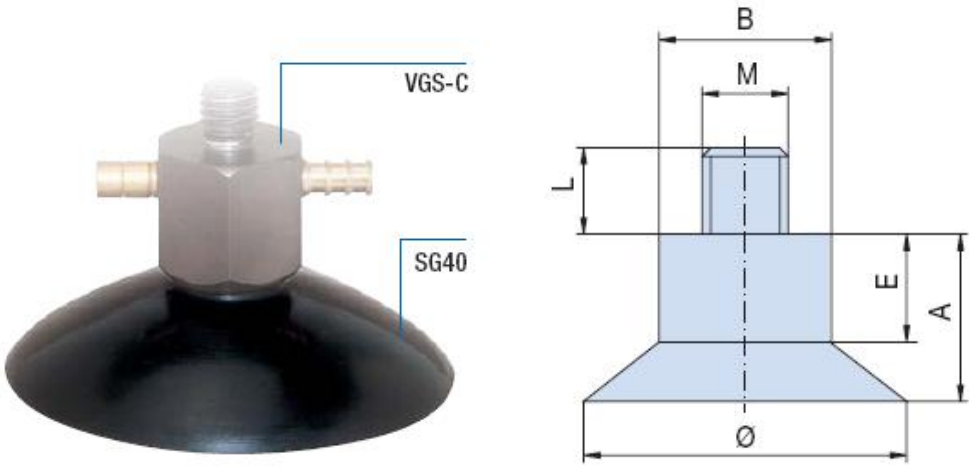
The grabbing vacuum force of the six cups is calculated with the help of relation (4)

$$F = \frac{3{,}14 \cdot 85^2}{4} \cdot 6 \cdot 0{,}5 \cdot 0{,}14 \cdot 0{,}7 = 1667{,}45\ N$$

$$F = 166{,}75\ daN$$

The projected vacuum grabbing device weights approximately 50 kg.

In picture 3 are presented the 3D and 2D drawings of the standard cylindrical vacuum cups, this type of cups being mostly used at the vacuum robot construction and for the vacuum grabbing device, having the right shape for grabbing the car body elements.



Picture 3. The 3D and 2D drawings of the cylindrical vacuum cups.

5. Conclusions

The robotisation of the auto body installation lines, brings the economic efficiency growth, by dropping the costs, and the realization time for a car body.

By using the vacuum system for grabbing the handled object, the grabbing device presented in the paper, it realizes a quick fixing and unfixing of the device, avoiding the object deterioration at grabbing and detaching. The realization concept of the device from modular elements brings to the time reduction for execution and so to the cost price reduction. The constructive optimization bring many possibilities for easy and quick adjusting of the cups positions, so that their axis will be perpendicularly on the grabbing surface, avoiding the accidental detachment of the car body element from the device.

Bibliography

[1.] Tocuţ, P. D. *Dispozitive de prehensiune vacuumatice optimizare constructive-funcţională*. Editura Universităţii din Oradea 2008 ISBN 978-973-759-599-7.

[2.] Tocuţ, P. D. *Optimizarea constructivă şi funcţională a dispozitivelor de prehensiune neconvenţionale* Teză de doctorat. Universitatea din Oradea 2007.

[3.] Tocuţ, P. D , Pop, A., Ţarcă, R. C. Functional model and simulation of pneumatic model, afferent to prehension vacuum device. 11th International Research/Expert Conference "Trends in the.Development of Machinery and Associated Technology" TMT 2007, Hammamet, Tunisia, 5-9 September, 2007.
[4.] P.D.Tocut, R.C.Tarca,I.C.Tarca,C.Tripe.V. THE FUNCTIONAL MODELLING AND SIMULATING OF A VACUUM PREHENSILE DEVICE, 5th International Vilnius Conference Euro-Mini Conference KORDS-2009.
[5.] Pavel Tocuţ, Radu Ţarcă, Călin Tripe Vidican, IoanŢarcă, *Optimizing a Vacuum Prehensile Device,* Revista Robotica & Management Vol.13,No.2,December 2008,6pp.ISSN 1453-2069.
[6.] P.D., Tocut, R.C.,Tarca, T.,Vesselenyi, C., Tripe Vidican - An Expert System For Determining The Structure And The Configuration Of The Vacuum Prehensile Devices Used In The Extraction Of The Injected Parts, PROCEEDINGS OF 4TH INTERNATIONAL CONFERENCE ON ROBOTICS November 13-14, 2008 Braşov, Romania Bulletin of the Transilvania Univ. of Braşov, Vol. 15(50), Series A, Special issue, ISSN 1223-9631, pag. 739-744.
[7.] P.D., Tocut, R.C.,Tarca, T.,Vesselenyi, C., Tripe Vidican -Constructive Optimizations of a Prehensile Vacuum device with Sideway Catch, PROCEEDINGS OF 4TH INTERNATIONAL CONFERENCE ON ROBOTICS November 13-14, 2008 Braşov, Romania Bulletin of the Transilvania Univ. of Braşov, Vol. 15(50), Series A, Special issue, ISSN 1223-9631, pag. 397-402.
[8] Giacomo Mantriota, Theoretical model of the grasp with vacuum gripper, Mechanism and Machine Theory 42 (2007) 2–17
[9.] Giacomo Mantriota, Communication on optimal grip points for contact stability, The International Journal of Robotics Research 18 (5) (1999) 502–513.
[10.] Giacomo Mantriota, Optimal grasp of vacuum grippers with multiple suction cups, Mechanism and Machine Theory 42 (2007) 18–33.
[11.] L. Mangialardi, G. Mantriota, A. Trentadue, A Three-dimensional criterion for the determination of optimal grip points, Robotics and Computer Integrated Manufacturing 12 (2) (1996) 157–167.
[12.] Gyungho Khima,b,_, Chun-Hong Parka, Husang Leea, Seung-Woo Kimb, Analysis of additional leakage resulting from the feeding motion of a vacuum-compatible air bearing stage, Vacuum 81 (2006) 466–474.
[13.] Roland Capsa,_, Hermann Beyrichena, Daniel Krausb, Stephan Weismannb, Quality control of vacuum insulation panels: Methods of measuring gas pressure, Vacuum 82 (2008) 691–699.
[14.] V.V. Anashina, R.V. Dostovalova, A.A. Krasnova, I.R. Collinsb, O.B. Malyshevc,*, Vacuum performance of a beam screen with charcoal for the LHC longstraig ht sections, Vacuum 72 (2004) 379–383.
[15.] Wu Y, Rong Y, Ma W, LeClair SR. Automated modular fixture planning: accuracy, clamping, and accessibility analysis. Robot Comput-Integr Manuf 1998;14:16–26.
[16] Wang MY, Pelinescu D. Optimizing fixture layout design in a point set domain. IEEE Trans Robot Automat 2001;17:312–23.
[17.] Yu Zheng_, Wen-Han Qian, A 3-D modular fixture with enhanced localization accuracy and immobilization capability, International Journal of Machine Tools & Manufacture 48 (2008) 677–687.
[18.] E.W. Endsley, E.E. Almeida, D.M. Tilbury_, Modular finite state machines: Development and application to reconfigurable manufacturing cell controller generation, Control Engineering Practice 14 (2006) 1127–1142.
[19.] Ho Choi, Muammer Koc-, Design and feasibility tests of a flexible gripper based on inflatable rubber pockets, International Journal of Machine Tools & Manufacture 46 (2006) 1350–1361.
[20.] R. Saravanan a,*, S. Ramabalan b, N. Godwin Raja Ebenezer c, C. Dharmaraja d, Evolutionary multi criteria design optimization of robot grippers, Applied Soft Computing 9 (2009) 159–172.
[21] Z.M. Bia, W.J. Zhangb,, I.-M. Chenc, S.Y.T. Langa, Automated geneartion of the D–H parameters for configuration design of modular manipulators, Robotics and Computer-Integrated Manufacturing 23 (2007) 553–562.
[22.] L. Mangialardi, G. Mantriota, A. Trentadue, A Three-dimensional criterion for the determination of optimal grip points, Robotics and Computer—Integrated Manufacturing 12 (2) (1996) 157–167.
[23.] ***Catalog FESTO – Automatizarea cu ajutorul pneumaticii.
[24.] ***Catalog NORGREN TOOLING 2008
[25.] ***Catalog NORGREN CLAMPS 2008
[26.] ***Catalog TUNKERS
[27.] *** Program de proiectare SolidWorks
[28.] *** Program de proiectare CATIA
[29.] http://www.tehno-sommer.com
[30.] http://www.balluff.com.com
[31.] http://www.tuenkers.de