

CONSIDERATIONS ON THE CONSTRUCTIVE DESIGN OF A ROBOTIC PREHENSION DEVICE DRIVEN BY SHAPE MEMORY ALLOY ELEMENTS

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Abstract: This paper presents the 3D model of a robotic prehension device driven by shape memory alloy elements, starting from the constructive-functional scheme. The 3D models of the device components are shown first, and then the device assembly in two variants: in open position, and in closed position.

Keywords: prehension device, constructive design, shape memory alloys.

1. Introduction

The accelerated development of automated processes has imposed the use of robots in various industrial and service applications.

The interface between the robot and the physical environment is the end effector, which can be a tool if the robot processes parts, or a prehension device (or gripper) if the robot manipulates objects.

The diversity of manipulation applications has led to the emergence of a multitude of variants of gripping devices, from solutions with classic drives (electric, pneumatic, hydraulic) to advanced variants driven with elements made of shape memory alloys (SMA) [12], [13], dielectric elastomers (DEA) [9], [10], electroactive polymers [9], etc.

To the prehension device proposed in this work, the driving is achieved by using an actuator which contains shape memory alloy (SMA) elements, a current variant compared to the classic actuation - electric, pneumatic or hydraulic.

Actuators with SMA elements have been studied in [2], [5], [7], [22], [23].

The use of SMA actuators in driving robot grippers has been analyzed in [1], [3], [4], [6], [14], [15], [16], [17], [18], [20]. SMA actuators find applications in cutting-edge fields where high positioning accuracy is required, such as biomedicine, aerospace and aviation, automobile industry, etc. [11].

Special attention is paid to the control system of actuators with SMA [8], evolving towards the use of neural networks [19].

The driving with SMA elements presents advantages such as [21]:

- constructive simplicity;
- compact and lightweight design;
- reduced overall dimensions;
- low kinematical errors;
- reduced power consumption;
- usage in the structure of grasping devices.

This paper presents the constructive-functional scheme, the operating principle and the 3D model of a robotic prehension device with SMA elements.

2. The Constructive-Functional Scheme

In the analyzed prehension device configuration, the conventional actuator (electric, pneumatic, etc.) is replaced with an SMA actuator.

The constructive-functional scheme is presented in figure 1.

The actuator is composed of the SMA element (1), the driving elements (2) and (3), and the springs (4) and (5). These components are assembled in a casing, solidarized to the fixed element (0).

The SMA element (1), designed as a cylindrical helicoidal spring, undergoes axial deformation (either extension or contraction), according to a specified control program. Thus, it generates the driving force and, respectively, the grasping force of fingers (6) and (7).

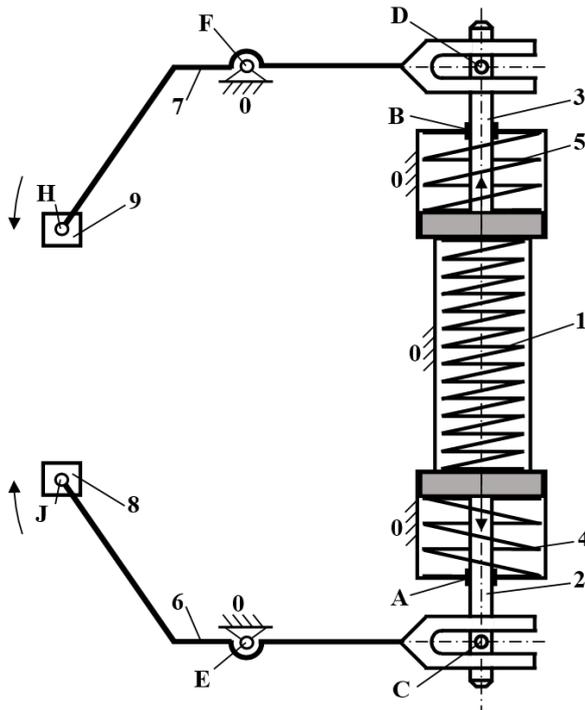


Fig. 1. The constructive-functional scheme of the prehension device [20], [21].

The SMA spring returning to its initial state, together with the elastic forces of helicoidal springs (4) and (5), determines the driving elements (2) and (3) to move back to their original positions, alongside fingers (6) and (7).

For an improved grasping performance, the fingers (6) and (7) are equipped with the jaws (8) and (9), respectively.

The components are linked through the translational kinematical joints A and B, the rototranslational kinematical joints C and D, and the rotational kinematical joints E, F, H, and J.

3. The 3D Model

Based on the constructive-functional scheme of the prehension device, the 3D models of the main components are designed and shown in figures 2 – 7.

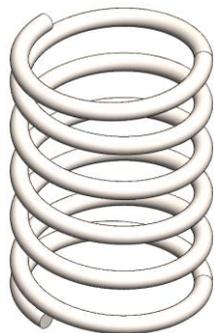


Fig. 2. The 3D model of the SMA spring.

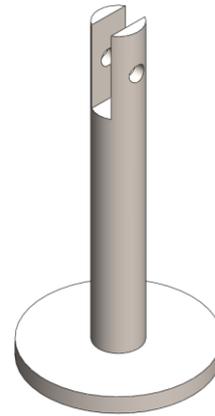


Fig. 3. The 3D model of the driving element.



Fig. 4. The 3D model of the spring.

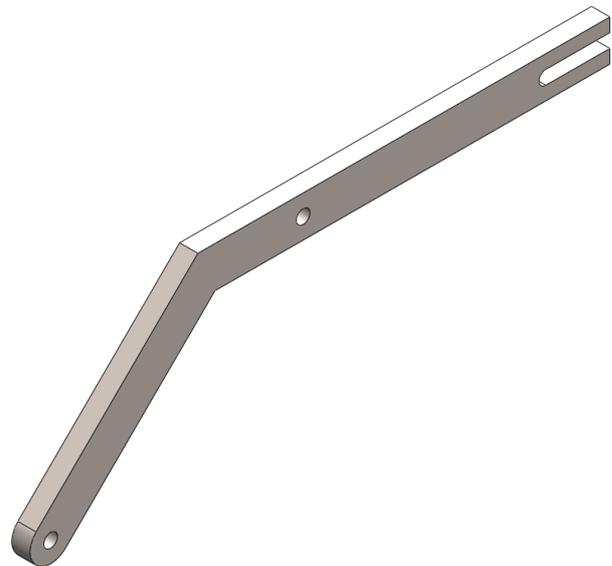


Fig. 5. The 3D model of the finger.

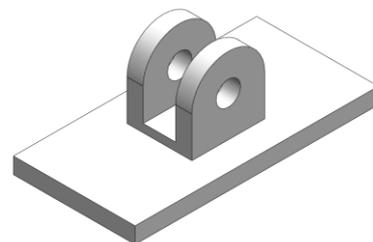


Fig. 6. The 3D model of the jaw.

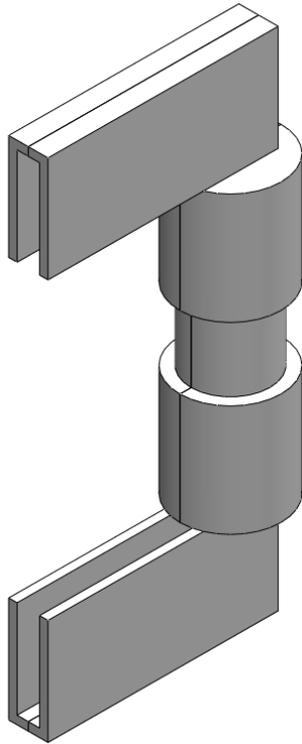


Fig. 7. The 3D model of the casing.

The 3D model of the device assembly is presented in figures 8 and 9, in open position and in closed position, respectively.

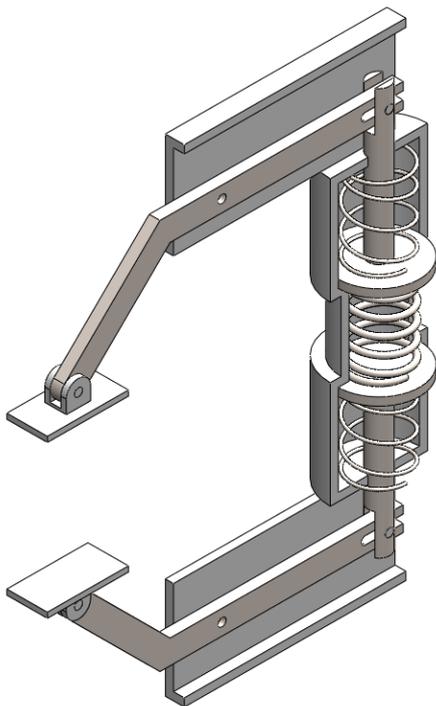


Fig. 8. The 3D model of device assembly, in open position.

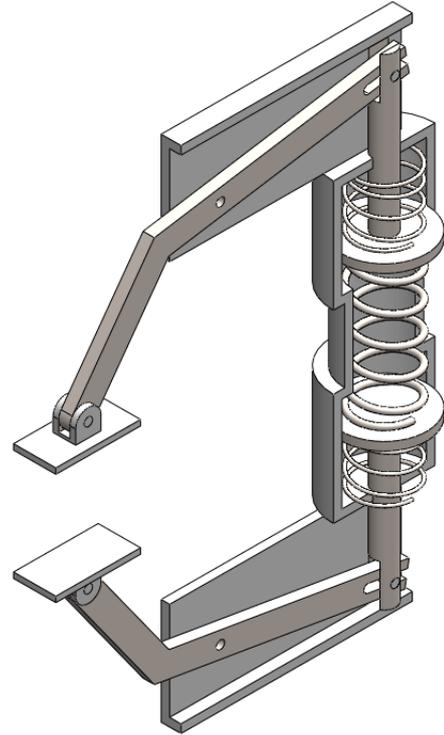


Fig. 9. The 3D model of device assembly, in closed position.

The constructive design through 3D modeling allows a great versatility, easily adaptable to other dimensions of the model being possible.

4. Conclusions

In order to improve the driving systems of the prehension devices, the paper presents a current variant, with SMA elements, simple from the constructive and functional point of view, with high reliability and positional precision.

The constructive simplicity of the proposed variant, with a reduced number of components, determines low manufacturing and maintenance costs.

3D modeling allows an adaptation of the achieved model to other dimensions and other positions of the components, facilitating the obtaining of new 3D models with different dimensions, equivalent from the functional point of view.

As a future research direction, the accomplishment of a physical model of the studied prehension device, in order to achieve experimental functional analysis, is proposed.

5. References

- [1] Amariei D., Vela I., Ziegler W.: „Implement of shape memory alloy actuators in a robotic hand”, *Analele Universității „Eftimie Murgu” Reșița*, Nr. 1, 2006, pp.15-18.

- [2] Amariei D., Meason Y., Vela, I.: „Analysis and Design of Thermal Actuators”, *Analele Universității „Eftimie Murgu” Reșița*, Nr. 1, 2007, pp.15-18.
- [3] Amariei D., Vela I.: „Shape Memory Alloys Actuators in Robotic Applications”, *Robotica & Management*, Vol. 12, No. 2, 2007, pp. 36-39.
- [4] Amariei D., Vela I., Gillich G.-R., Răduca E.: “Shape memory alloy actuator for robotic grippers actuated by two pairs of active springs”, *The 20th International DAAAM Symposium "Intelligent Manufacturing & Automation: Theory, Practice & Education"*, 25-28th November 2009, Viena, Austria, *Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium*, pp. 1307-1308.
- [5] Amariei D., Vela I., Gillich G.-R., Micloșină C.O.: “Model Equations of Shape Memory Effect – Nitinol”, *Analele Universității “Eftimie Murgu” Reșița*, Fascicula de Inginerie, anul XVII, Nr. 2, 2010, pp. 11-16.
- [6] Amariei D.D.: “Cercetări privind dispozitivele de prehensiune acționate de actuatori din aliaje cu memoria formei ale roboților industriali / Research on prehension devices driven by shape memory alloy actuators of industrial robots”, doctoral thesis, scientific coordinator Vela I., “Eftimie Murgu” University of Resita, 2015.
- [7] Bizau I.V.: “Cercetări privind construcția și funcționarea transmisiilor armonice, având generatorul de unde cu elemente din aliaje cu memoria formei / Research on the construction and operation of harmonic transmissions, having wave generator with shape memory alloy elements”, doctoral thesis, scientific coordinators Vela I., Nedelcu D., “Eftimie Murgu” University of Resita, 2014.
- [8] Cheng S.S., Kim Y., Desai J.P.: “Towards Real-Time SMA Control for a Neurosurgical Robot: MINIR-II”, *Robotics Research*, Vol 1, pp. 187-200, 2018.
- [9] Dzedzickis A., Petronienė J.J., Petkevičius S., Bučinskas V.: “Soft Grippers in Robotics: Progress of Last 10 Years”, *Machines*, 12, 887, 2024, <https://doi.org/10.3390/machines12120887>
- [10] Gupta U., Qin L., Wang Y., Godaba H., Zhu J.: “Soft Robots Based on Dielectric Elastomer Actuators: A Review”, *Smart Mater. Struct.*, 2019, 28, 103002.
- [11] Jadhav M.R., Singh S., John P. et al. Advancements and recent trends in shape memory alloy actuators: position control and emerging applications. *Int. J. Dynam. Control*, 13, 114, 2025, <https://doi.org/10.1007/s40435-025-01615-8>
- [12] Kelemen M., Kelemenova T., Virgala I., Mikova L., Prada E., Varga M., Semjon J., Sukop M., Janos R.: “Robotic gripper actuated using the shape memory alloy actuators”, *MM Science Journal*, March 2022, https://doi.org/10.17973/MMSJ.2022_03_2022015
- [13] Liu M., Hao L., Zhang W., Zhao Z.: “A novel design of shape-memory alloy-based soft robotic gripper with variable stiffness”, *International Journal of Advanced Robotic Systems*, vol. 17, issue 1, 2020, <https://doi.org/10.1177/1729881420907813>
- [14] 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, pp. 451-452.
- [15] Modabberifar M., Spenko M.: “A shape memory alloy-actuated gecko-inspired robotic gripper”, *Sensors and Actuators A: Physical*, vol. 276, pp. 76-82, June 2018, <https://doi.org/10.1016/j.sna.2018.04.018>
- [16] Schmelter T., Bade L., Kuhlentötter B.: “A two-finger gripper actuated by shape memory alloy for applications in automation technology with minimized installation space”, *Actuators*, vol.13, no.10, art. No. 425, 2024, <https://doi.org/10.3390/act13100425>
- [17] Sinkar A., Pandey A., Mehta C., Karthick S., Jayachandran S., Akash K., Palani I.A.: “Design and Development of Wall Climbing Hexapod Robot with SMA Actuated Suction Gripper”, *International Conference on Robotics and Smart Manufacturing (ROSMA2018)*, *Procedia Computer Science*, Vol. 133, pp. 222-229, 2018.
- [18] Takumi I., Sumito N.: “SMA micro-hand implemented in small robot for generating gestures”, *Intelligent Service Robotics*, Vol. 14, Issue 3, pp. 399-408, 2021.
- [19] Uleru G.-I., Hulea M., Burlacu A.: “Bio-Inspired Control System for Fingers Actuated by Multiple SMA Actuators”, *Biomimetics*, 7, 62, 2022, <https://doi.org/10.3390/biomimetics7020062>
- [20] Vela I., Vela D.G., Miclosina C.: “Dispozitiv de prehensiune acționat cu elemente din aliaje cu memoria formei / Prehension device actuated with elements made of shape memory alloys”, patent application RO134829 (A0), OSIM – Oficiul de Stat pentru Invenții și Mărci / State Office for Inventions and Trademarks, 2020.
- [21] Vela D.-G., Vela I., Miclosina C.-O.: „Kinestostatics of a Robotic Prehension Device Driven by Shape Memory Alloy Elements”, *Robotica & Management*, vol. 28, no. 2, December 2023, pp. 55-58. <https://doi.org/10.24193/rm.2023.2.10>
- [22] Wang J.H., Xu, F., Yan S., Wen S.Z.: „Electrothermal driving mechanism for SMA spring actuators”, *Materials Science Forum*, 423-424, 461-466, 2003.
- [23] Waram T.: “Design Principles for Ni-Ti Actuators”, *Engineering Aspects of Shape Memory Alloys*, Butterworth-Heinemann, London, pp. 234-244, 1990.