

Article

Not peer-reviewed version

---

# The Development of a Nitinol Angular Actuator

---

[Oana Vasilica Grosu](#) <sup>\*</sup>, [Laurențiu Dan Milici](#) <sup>\*</sup>, [Mihaela Paval](#)

Posted Date: 13 February 2025

doi: 10.20944/preprints202502.1035.v1

Keywords: Smart memory alloy; Nitinol; actuator; engineering, bibliometric, VOSviewer



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a Creative Commons CC BY 4.0 license, which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Article

# The Development of a Nitinol Angular Actuator

Oana Vasilica Grosu \*, Dan Laurențiu Milici \* and Mihaela Pavăl

University Ștefan cel Mare of Suceava, vasilica.grosu@usm.ro, dam@usm.ro, mpoienu@usm.ro

\* Correspondence: vasilica.grosu@usm.ro, dam@usm.ro.

**Abstract:** Shape memory alloys are the key to sustainable technology and future industries. One of the most highlighted alloys around these times is Nitinol. It has special properties to work in extreme conditions and it can be specially projected for specific tasks. The Nickel-Titanium alloy is tested by NASA to build a new type of wheel to be used for future rovers which will be sent to Mars. Other recently known devices to be built using this material are stents, root canal files, arches, bone implants used in medicine, aerospace gas turbines engines, thermal bimorph or dynamic actuators used in engineering, innovative SC brace or seismic retrofit applications in seismology and the list can continue. The purpose of this paper is to introduce the angular actuator that has as a main component a Nitinol spring. In the theoretical part we identified the newest solutions in the sphere of Nitinol devices and presented them through the perspective of bibliometric maps obtained with the software VOSviewer. We focused on articles which analyze and improve the NiTi alloy in order to create a wider applicability range for it, studies over the already existing devices, testing models, novel applications and devices which utilize it and papers identifying new applications for actual NiTi devices/ equipment. Conclusions on the subject are that the industry is more and more interested in the shape memory materials and are open to investing in the research of the Nitinol. The presented device was physically developed and tested at the University Ștefan cel Mare of Suceava. Some results on the testing of the device are presented and discussed in this paper.

**Keywords:** smart memory alloy; nitinol; engineering; bibliometric; VOSviewer

## 1. Introduction

The latest trends express more and more the need to adapt, to reuse and to repair due to the huge impact human production and consuming has over our planet. Our ancestors were used to live modestly and respecting the limits of the nature, but in today's market of offer and request the bigger the economy the bigger and more negative are the effects on land, water and air. This is the reason we selected Nitinol, a material that can be used for the same action multiple times.

In recent years the industry requests innovative solutions and materials to be used in actuators. One of the most researched branches nowadays are the shape memory alloy actuators. For example, the Nitinol actuators can be produced in multiple configurations and models depending on the alloy shape among other devices or equipment.

We focused on articles which analyze and improve the NiTi alloy in order to create a wider applicability range for it, studies over the already existing devices, testing models, novel applications and devices whom utilize it and papers identifying new applications for actual NiTi devices/ equipment.

## 2. State of the Art

In this paper we combined and analyzed 145 articles which include nitinol researches in its various shapes and forms. The purpose of this article is to highlight the new trends in the field of nitinol devices/ equipment/ forms/ applications through the bibliometric maps and to present a new actuator built with Nitinol.

Using the classification method, we highlighted the main forms of used NiTi and their main applications and domains. The article also brings up the innovative elements developed around the world by various institutes and laboratories over the last 6 years.

This article is structured in seven parts: the introduction places the theme of Nitinol, then in the state of the art the selected articles are represented with the purpose they have on the implemented system. In the third part the material and methods used are placed followed by the fourth part of the theoretical analysis of the articles. The fifth section is analyzing the resulting bibliometric maps from the network and temporal perspective. The following part presents the use of a Nitinol memorized spring to build an angular actuator. Finally, discussions and conclusions are identified in order to evolve to future directions of this research.

### 3. Materials and Methods

We selected the platform Web of Science and IEEE due to their wide variety of articles and its complexity. The selected articles are from the area of Nitinol devices and equipment, from two time periods and the wide category includes the other one. There have been made multiple analysis in this article and they involve a certain number of articles.

The included researches resulted through articles filtrations on Web of Science on the Nitinol published in the areas of Web of Science:

- Materials Science Multidisciplinary;
- Engineering Biomedical;
- Engineering Electrical Electronic;
- Engineering Manufacturing;
- Engineering Multidisciplinary;
- Orthopedics;
- Robotics;
- Engineering aerospace;
- Engineering Industrial.

The extensions RIS (for the 145 articles) extensions were downloaded and used in the VOSviewer software [156] to generate network visualization bibliometric maps, density and the overlay visualization map.

The software VOSviewer [156] uses network data generates multiple types of bibliometric maps. The maps can be visualized and explored for more detailed perspectives providing access to every element identified in the map. The generated maps can be recreated by anyone using the program with the condition to apply the same rules.

The advantages of such an analysis are:

- to provide original content;
- to observe connections and similitudes among the article;
- to guide to specific content the researcher highlighting the novel path in the area;
- to explore the evolution of a certain theme in time.

### 4. Theoretical Analysis

In this section we are presenting three classifications, respectively first one is the classification after the generalized main objective, one after the form of the used Nitinol and after the main domain of application.

#### 4.1. Classification after the Generalized Main Objective

Every studied article contains one or multiple types of Nitinol in different structures and compositions projected to have certain characteristics and to respond in electrical or thermal field. In Figure 1 are presented 19 forms of Nitinol with the articles they were found in.

We conceived this classification in order to provide a clear orientation for all the researchers who want to easily identify specific information regarding a certain type of nitinol. Firstly, we identified the main objective of every analyzed article and then simplified them and integrated them in one of the 7 categories presented in Table 1.

**Table 1.** Classification after the generalized main objective.

Generalized main objective	Reference
To improve the device fabrication	[5,153]
To fabricate new NiTi alloys	[4,23,150,154]
To test models/ strategies on a device based on Nitinol	[9,21,27,44,143,144,148,149,155]
To build a new device/ equipment/ application/ model	[17,18,32,33,70,81,82,85,105,131,136,139,140,147,151,152]
To improve the characteristics of an already existing device/ equipment/ application/ model/ process	[1–3,7,8,10,15,20,28,31,38,59,63,72,80,104,106,107,121,127,130,132,134,135,137,141,142,146]
To study/ test device/ equipment/ applications	[22,25,29,37,39–42,53,54,68,75,83,87,90,94–96,98,101–103,117,118,121–123,126,129,138,145]
To study/ test the NiTi alloy	[6,11–14,16,19,24,26,30,34–36,43,45–52,55–58,60–62,64–67,69,71,73,74,76–79,84,86,88,89,91–93,97,99,100,116,119,120,125,128]

From a total of 147 articles 38% are focused on studying and testing the Nitinol alloy on different levels: dynamic fracture performances, evolution during cooling and heating on molecular level, martensite variant reorientation process, torsion and bending deformation modes, to capture the shear strain field, etc. A percentage of 21% from the researchers are studying/ testing the device/ equipment/ applications such as the micro-lattices/stents, MEMS applications, welding, actuators, biomedical devices, electrochemical micromachining, chips, power laser actuation, cement mortar beams and so on.

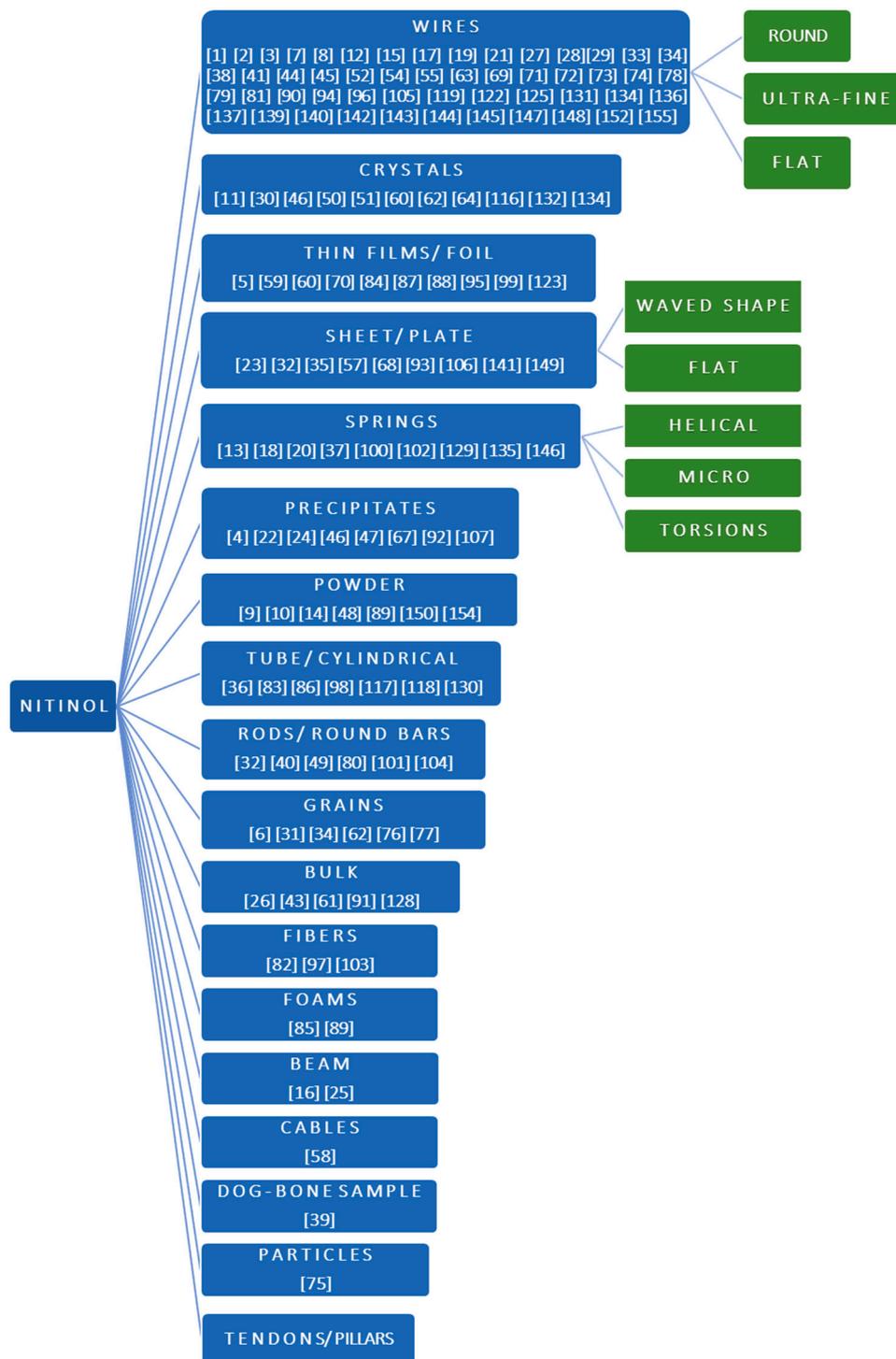
Another 19% of them work to improve the characteristics of already existing devices/ equipment/ applications/ model/ process on medical robots, reduction of the surface defects, reversible bending on electrical actuators, effectiveness of Auricchio model, minimize hysteresis, lower prices, obtain useful transformation temperatures, rise spring actuation performance, wastewater recovery, adhesion increase, etc. Also 10% build a new device/ equipment/ applications/ model like: ankle rehabilitation robot, applications on the material behavior and lifespan, develop additive manufacturing, micropump diaphragm, form fit connection, 3D models and built numerical simulation.

A reduced percentage of articles, 6,13% of them are testing models/ strategies on devices based on Nitinol: The Auricchio model, numerical one, three-dimensional phenomenological constitutive model and diffraction computed tomography. The smallest percentage, 1,36% and 2,72 % of the papers work to develop a new formula of Nitinol, respectively to improve the fabrication of devices using Nitinol.

#### 4.2. Classification After the Nitinol form

Every studied article contains one or multiple forms of Nitinol in different structures and compositions projected to have certain characteristics and to respond in electrical or thermal field.

We conceived this classification in order to provide a clear orientation for all the researchers who want to easily identify specific information regarding a certain type of Nitinol. In the following Figure 1 are listed 19 forms of Nitinol with the articles they were found in.



**Figure 1.** Forms of Nitinol.

#### 4.3. Classification After the Application Domain

Nitinol has such a wide variety of applications due to its shape memory feature activated at temperature changes, superelasticity (pseudoeelasticity), corrosion resistance, anti-toxicity, good shock absorption characteristics, large range of temperature response depending on the atomic percentages of the Nickel and Titan and so on.

The medical field takes the first place when it comes to researches in the area of Nitinol applications and studies. Then the engineering field with a wide variety of devices, then civil engineering, robotics and so on. Definitely the charts would be different if we would compile

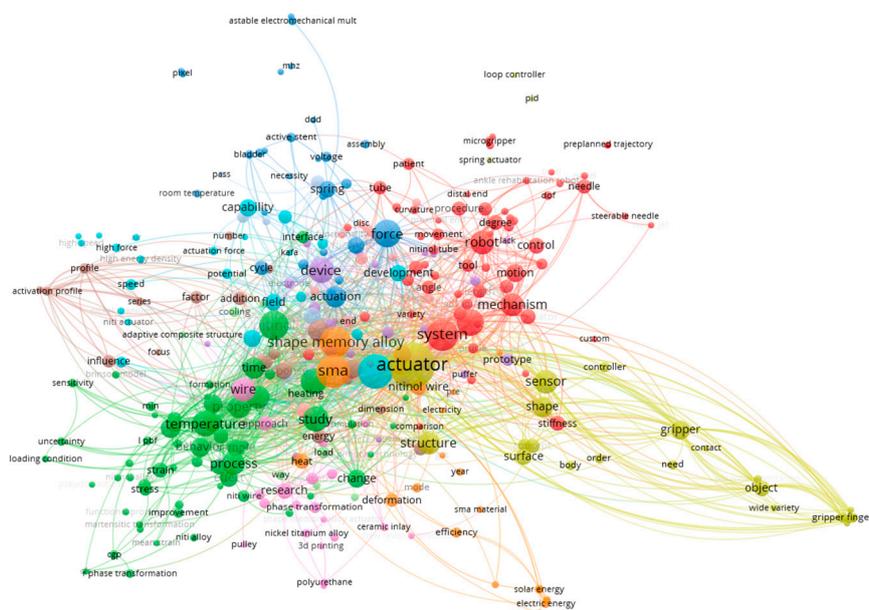
multiple publication platforms. The following classification lists some of the identified utilization fields and the main applications of the Nitinol:

- Medical:
  - Blood pressure sensors on the head of a pin;
  - Root canal files;
  - Arches, stents;
  - Spinal and dental implants;
  - Vascular stent;
  - Eyeglass frame;
  - Micro-stent;
  - Bone implant;
  - Orthodontic wires;
  - Minimally invasive surgical devices;
  - Robotic needle insertion;
  - Stents;
  - Valves;
  - Muscles.
- Engineering:
  - Rotary actuator;
  - Actuator;
  - Aerospace gas turbine engines;
  - Dynamic actuators
  - Actuators used for helicopter active rotor blade control;
  - Thermal bimorph actuators;
  - Sensor-less actuator.
- Civil Engineering Industry:
  - High damping materials;
  - Thin-wall structures;
  - Grate;
  - Micro-lattice;
  - NiTi foil for welding.
- Robotics:
  - Artificial muscle;
  - Micro-actuators;
  - Bionic manipulator.
- Automotives:
  - Actuators;
  - Motors;
  - MEMS.
- Seismology:
  - Innovative SC brace;
  - Seismic retrofit applications.
- Constructions: Cement mortar beams.
- Mechanical: Pressure sensors.

## 5. Bibliometric Simulation Analysis

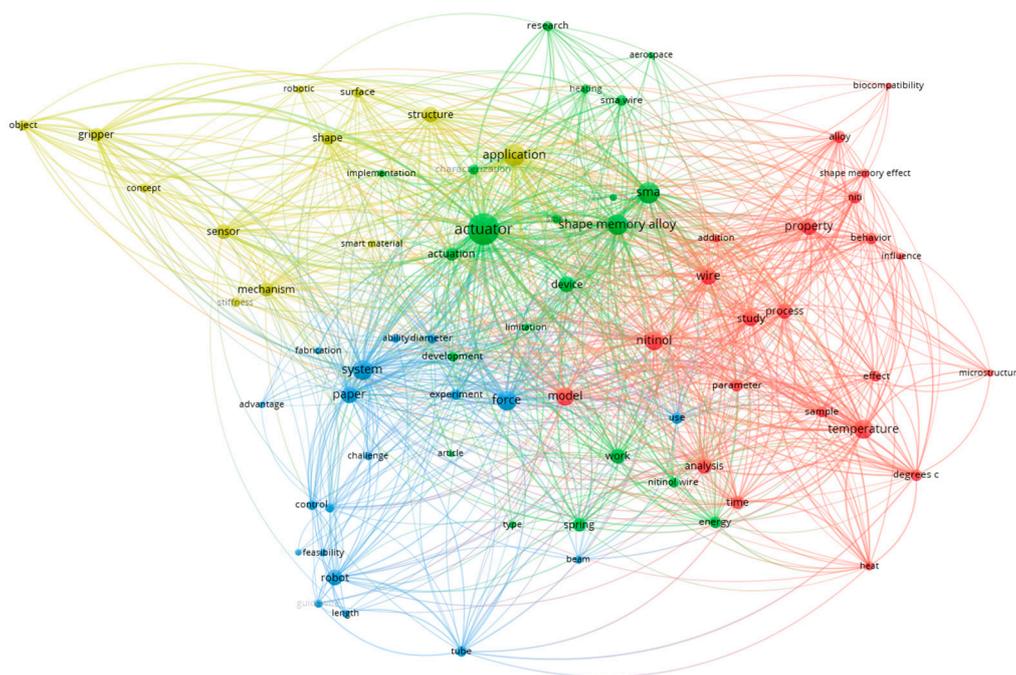
### 5.1. Network Visualization

Thousands of elements are presented under multiple perspectives and environments, which slowly evolve under the name of development and evolution in science. The following Figure 2 highlights 480 items which have been present in our 110 analyzed articles at least for 5 times.



**Figure 2.** Network visualization for items identified at least 5 times.

In order to clarify the presentation new increased the number of appearances per item to at least 10 appearances and now the map in Figure 3 is presenting the 74 most used items in the selected articles.



**Figure 3.** Network visualization of the items with at least 15 occurrences.







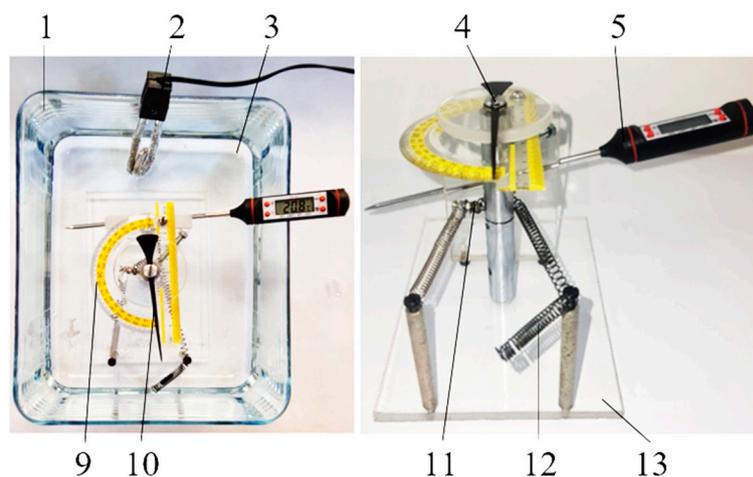
- ♣ Diameter of the coil: 6 mm;
- ♣ Total length: 76,2 mm;
- ♣ Stretching capacity: x 4
- ♣ Transition temperature: 45 °C.

### 6.2. Constructive Description

The actuator (Figure 9) consists of a Nitinol spring (15) with a coil diameter of 1.15 mm, a rest length of 30 mm, a coil circumference of 6 mm and a 30 mm reserve (12) from which the system can be tensioned or relieved, a compensating steel spring (6), a spring clamping system (11) and a spring tension and spring contraction monitoring system. The axis of rotation of the actuator (16), on which the adjusting rod (17) is installed, and the two supports for supporting the steel and Nitinol springs (14) are mounted perpendicular to the base plate (13).

In the construction of the angular actuator test stand, we used a heat-resistant vessel (1) in which we placed the actuator in liquid media (3). The liquid was heated by means of a thermocouple (2) mounted on the rim of the thermal vessel. The temperature variation was measured with a thermometer (5) attached to the holder (8), and the protractor (9) for visualizing the angle of displacement of the indicator needle (10) is mounted on the holder (7). The indicator needle is located on the end of its holder (4) which is clamped in the support plate (18).

The Nitinol spring is memorized so that at a temperature above 40° C it expands, and at temperatures lower than the previous value it returns to its original shape.



**Figure 9.** Nitinol actuator.

### 6.3. Description of Actuator's Operation

The data was acquired using the experimental stand presented in Figure 14. The actuator is positioned in the heat-resistant vessel (1) which creates the favorable operating environment by storing the fluid (water). Using the thermowell (2) the temperature of the fluid will be controlled to observe the behavior of the Nitinol (15) in stages, the expansion of the spring with increasing temperature and the contraction of the steel spring (6).

In the second part, the thermoplunger is taken out of the immersion (water) medium (3) for cooling and contraction of the Nitinol spring and detensioning of the steel spring, respectively.

The temperature of 30 °C will be considered as the starting point of the Nitinol spring deflection, and after the temperature of 90 °C the spring will not deflect. The liquid temperature was raised to 95 °C, but there was no further reaction after this threshold. The ambient temperature at the time the experiment was started was 20 °C.

Several displacement positions of the Nitinol spring-loaded actuator are shown in the following Figure 10, the initial position at 0, 10°, 20°, and 158° displacements.

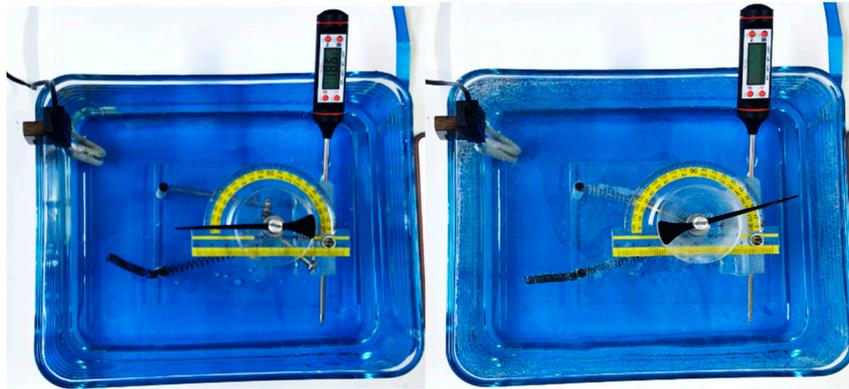


Figure 10. Angular displacement of the angular actuator on heating.

## 7. Experimental Data Collection

For data acquisition, the stand was submerged in water and, by varying the temperature, the Nitinol spring causes the actuator to contract and relax, or angular displacement.

The following Figure 11 shows the characteristic of actuator displacement as a function of heating temperature. The amount of displacement is relatively small between 20 °C and 40 °C, but the displacement visibly increases with temperature. A jump occurs between 50 °C and 60 °C when the displacement increases from 26° to 40°. The characteristic emphasizes the sudden displacement that the actuator makes when the liquid medium reaches a temperature of 80 °C and 150 °, respectively. At 90 °C the displacement reaches 158°. Even if the temperature was raised to 95 °C the displacement angle remained the same.

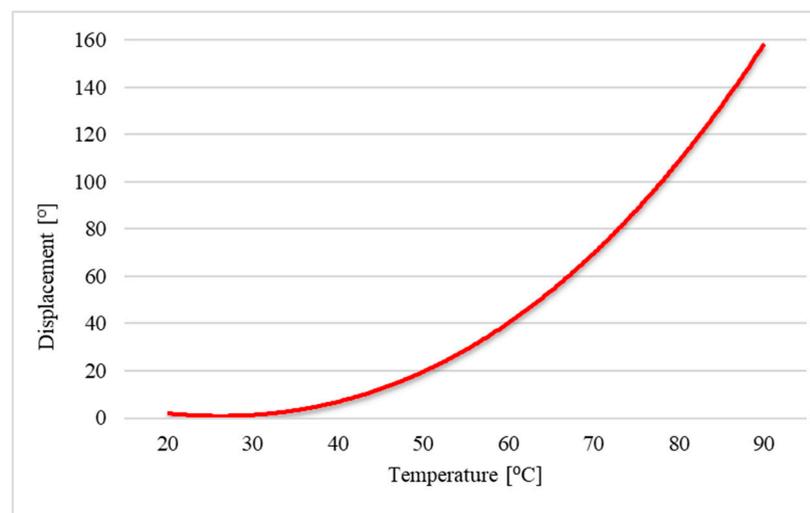
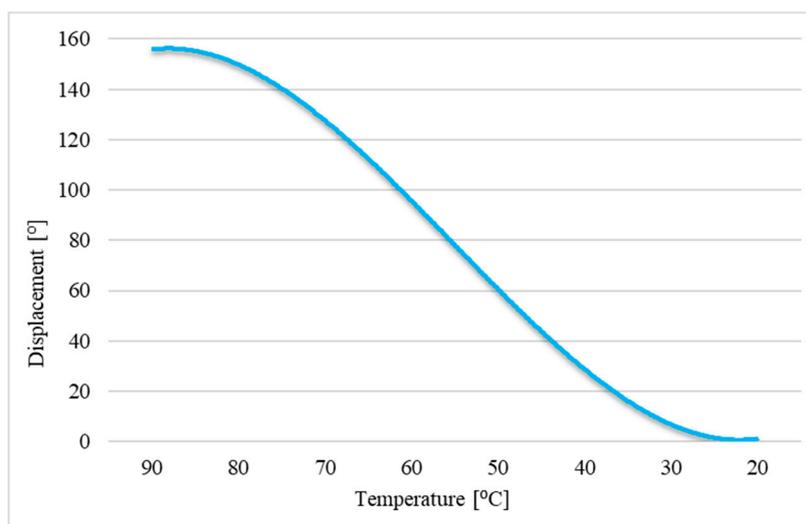


Figure 11. Characteristics of the actuator displacement versus heating temperature.

The characteristic of the angular displacement of the actuator (Figure 12) as a function of cooling temperature shows the constant angular displacement of the actuator up to a temperature of 60 °C at which the Nitinol spring contracts to an angle of 50°, followed by continuous cooling with small contact jumps until it returns completely to its initial position at 20 °C.



**Figure 12.** Actuator angular displacement versus cooling temperature characteristic.

## 8. Discussions and Conclusions

The theoretical analysis conducted at point 4 in our research contains 3 classifications. The first one (section 4.1.) is the one after the main objective of the selected papers and we generalized it so it would fit in one of the 7 categories. This allows us to provide a more focused perspective over the Nitinol researches. The majority of authors are concentrating on the studying and testing of the alloy with the purpose to offer higher efficiency, better characteristics, improved rearmament and so on to make the Nitinol better known and more used on the market. The classification after the form (section 4.2.) of Nitinol used help the researchers that would consult our paper to easily identify the articles that addresses the use of a specific form of Nitinol.

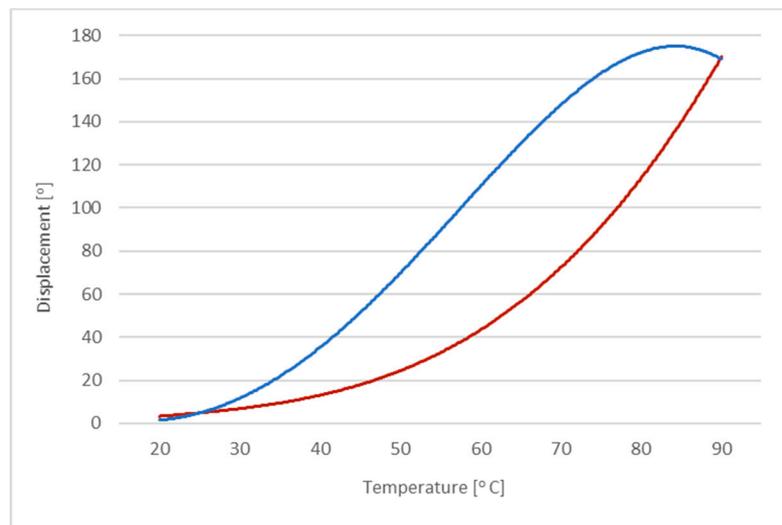
The classification after the application domain (section 4.3.) we included a reduced part of the devices/ equipment/ applications that were developed in the selected articles. A large part of them is in the domain of the medical/ biomedical field such as: orthodontic wire, root canal files, valves, stents, micro stent, robotic needle, spinal and dental implants, etc. Another domain which highlights the deep research into the Nitinol area is engineering with actuators, aerospace gas turbines, thermal bimorph actuators and so on, then some civil engineering industry examples were identified: grates, micro-lattice, thin wall structures, etc.

The bibliometric simulation analysis from point 5 gives us the visual perspective using bibliometric maps and generating network visualizations, temporal and geographical analysis. On a broad approach the network visualization exhibits all the items most identified on the titles and abstracts of the selected articles. We highlighted some of the items we find more important: "smart memory alloy", "NiTi", "application", "device", "actuator", "performance". The temporal perspective includes all this elements and positions then in different moments of research. For example the element "application" is predominantly identified around 2020, while the focus on the cooling process has been increased around 2022. Among the years the interest for the Nitinol has increased and its development is continuous providing new solutions to improve and discover novel devices and applications.

One of the most relevant maps that we inserted in this article is the overlay visualization map which contains the 147 selected articles from 1018 to 2024 from the platform Web of Science. This map is relevant because reveals the evolution of Nitinol in the researches and highlights the main subjects that have been reached on this topic in each year.

The behavior of the angular actuator upon heating with a heat gun, i.e., natural cooling of the Nitinol spring in liquid medium is visible in Figure 20 which was obtained by polynomial interpolation of the points to order 3. It is concluded that at the temperature of 90 °C the maximum

angle of displacement, i.e.  $158^\circ$ , is reached in a time of about 45 minutes and the return from the temperature of  $95^\circ\text{C}$  to that of  $20^\circ\text{C}$ , i.e. to the initial position is after 207 minutes, reaching the memorized shape.



**Figure 13.** Behavior of the angular actuator during natural heating and natural cooling of the nitinol spring in liquid medium. The red curve represents the displacement with increasing temperature and the blue curve represents the displacement with cooling.

Analyzing the heating displacement curve, it can be observed that in the range  $20^\circ\text{C}$  -  $30^\circ\text{C}$ , the displacement in relation to the temperature increase occurs slowly and at insignificant values. After the temperature of  $30^\circ\text{C}$  the actuator changes its behavior, the displacement occurs linearly up to the temperature of  $75^\circ\text{C}$ , every  $10^\circ$  increase in temperature by  $10^\circ$  a displacement of  $30^\circ$  occurs. After a temperature of  $70^\circ\text{C}$  the displacement stabilizes, its variation with temperature being very small.

## 8. Future Directions

This research has its roots in older studies and researches from our laboratory, such as: devices with intelligent materials [108] used in energetics, special actuators [102], electro and thermomechanical actuators [109] linear heliothermic actuator [110], electromechanical micropump [111] and we used Nitinol to study its lifespan [18] and to develop special actuators and materials with shape memory [112], clutch type thermocouple [113], Nitinol operated Micropump [114], a locking system [115] and we hope it will result in the development of newer devices and equipment with applications in electrical engineering.

Shape memory alloys or smart materials are used in small and large scale structures in multiple fields such as robotics, engineering, medical devices, automotives, aeronautics, aerospace, mechanical engineering, power plants and biomedical fields (microsensors, stents, cement mortar beams, artificial muscle, micro-actuators, bionic manipulator, etc.).

In future research we can identify the form of Nitinol that is appropriate for each applicability domain. There are certain connections between the type of used Nitinol, related to its elasticity and durability, and the shapes it used in certain applications.

In the perspective of a more precise research there could be made a classification after the chemical composition/ formula of the Nitinol alloy, but this is out of our expertise area. This article can be also extended increasing the number of the analyzed articles, analyze a higher number of items or finding various classifications appropriate for a review.

The future of the research in this area is taking fast steps and the trends are always going to change. The industries are more and more interested to invest in researches that use smart materials

as an alternative for the classic ones. Our future directions are leading to more deepen and precise research in the field of Nitinol devices.

**Author Contributions:** Conceptualization, L.D.M., O.V.G. and M.P.; methodology, L.D.M.; software, O.V.G. and M.P.; validation, L.D.M., O.V.G. and M.P.; formal analysis, L.D.M. and O.V.G.; investigation, L.D.M. and M.P.; resources, L.D.M., O.V.G. and M.P.; data curation, O.V.G.; writing—original draft preparation, L.D.M., O.V.G. and M.P.; writing—review and editing, O.V.G. and M.P.; visualization, O.V.G.; supervision, L.D.M.; project administration, L.D.M.; funding acquisition, M.P. All authors have read and agreed to the published version of the manuscript.

**Funding:** This paper has been financially supported within the project entitled “DECIDE – Development through entrepreneurial education and innovative doctoral and postdoctoral research, project code POCU/380/6/13/125031, project co-financed from the European Social Fund through the 2014-2020 Operational Program Human Capital”.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Dezaki, M.L.; Bodaghi, M.; Serjouei, A.; Afazov, S.; Zolfagharian, A. Adaptive reversible composite-based shape memory alloy soft actuators, *Sensors and Actuators A: Physical* **2022**, Volume 345, Pages 113779-113793, doi: 10.1016/j.sna.2022.113779.
2. Karimi, S.; Konh, B. Kinematics modelling and dynamics analysis of an SMA-actuated active flexible needle for feedback-controlled manipulation in phantom, *Medical Engineering & Physics* **2022**, Volume 107, Page 103846, doi: 10.1016/j.medengphy.2022.103846.
3. Chaudhari, R.; Prajapati, P.; Khanna, S.; Vora, J.; Patel, V.K.; Pimenov, D.Y.; Giasin, K. Multi-Response Optimization of Al<sub>2</sub>O<sub>3</sub> Nanopowder-Mixed Wire Electrical Discharge Machining Process Parameters of Nitinol Shape Memory Alloy. *Materials* **2022**, Volume 15, Pages 1-21, Doi: 10.3390/ma15062018.
4. Zhang, D.; Hu, Z.; Li, Y.; Cong, W. Excellent damping properties and their correlations with the microstructures in the NiTi alloys fabricated by laser-directed energy deposition, *Journal of Manufacturing Processes* **2022**, Volume 84, Pages 965-976, doi: 10.1016/j.jmapro.2022.10.047.
5. Sahu, A.; Palani, I.A.; Singh, V. Investigation on fabrication of NiTi based strain gauge using laser decal transfer based  $\mu$ -3D printing, *Manufacturing Letters* **2022**, Volume 32, Pages 49-53, doi: 10.1016/j.mfglet.2022.03.001.
6. Cui, Y.; Zeng, X.; Tan, V.B.C.; Zhang, Z. Experimental and numerical studies of NiTi dynamic fracture behaviors under the impact loading, *International Journal of Mechanical Sciences* **2022**, Volume 235, Pages 107724-107750, doi: 10.1016/j.ijmecsci.2022.107724.
7. Britz, R.; Motzki, P. Analysis and evaluation of bundled SMA actuator wires, *Sensors and Actuators A: Physical* **2022**, Volume 333, Pages 113233, doi: 10.1016/j.sna.2021.113233.
8. Zhang, M.; Duan, Y.; Fang, X.; Zhang, H.; Jiao, G.; Li, Y.; Huang, K. Tailoring the superelasticity of NiTi alloy fabricated by directed energy deposition through the variation of residual stress, *Materials & Design* **2022**, Volume 224, Pages 111311-111352, doi: 10.1016/j.matdes.2022.111311.
9. Chekotu, J.C.; Kinahan, D.; Goodall, R.; Brabazon, D. Influence of Structural Porosity and Martensite Evolution on Mechanical Characteristics of Nitinol via In-Silico Finite Element Approach. *Materials* **2022**, Volume 15, Pages 5365-5391, doi: 10.3390/ma15155365.
10. Kannan, R.R.; Sivabharathy, M.; Lenin, N. Shape memory effect of CuxAl<sub>1-x</sub>nitinol/MWCNT nanocomposites for actuators in MEMS, *Sensors and Actuators A: Physical* **2022**, Volume 334, Pages 113327-113338, doi: 10.1016/j.sna.2021.113327.

11. Liu, S.; Ke, C.B.; Cao, S.; Ma, X.; Zhao, Z.X.; Li, Y.W.; Zhang, X.P. An atomistic study of self-accommodation martensite morphologies and microstructure evolution during forward and reverse martensitic transformations in single crystal and bicrystal NiTi alloys, *Computational Materials Science* **2022**, Volume 210, Pages 111455-111470, doi: 10.1016/j.commatsci.2022.111455.
12. Kong, X.; Hao, S.; Ren, Y.; Yang, Y.; Feng, B.; Guo, F.; Yang, Q.; Huang, B.; Cui, L. Interactions between martensitic NiTi shape memory alloy and Nb nanowires in composite wire during tensile deformation, *Composites Part B: Engineering* **2022**, Volume 234, Pages 109690-109702, doi: 10.1016/j.compositesb.2022.109690.
13. Zhang, Y.; Yu, C.; Zhu, Y.; Kan, Q.; Kang, G. Thermo-mechanically coupled deformation of pseudoelastic NiTi SMA helical spring, *International Journal of Mechanical Sciences* **2022**, Volume 236, Pages 107767-107789, ISSN 0020-7403, doi: 10.1016/j.ijmecsci.2022.107767.
14. Jsaefi, K.; Nematollahi, M.; Bayati, P.; Kordizadeh, F.; Andani, M.T.; Abedi, H.; Poorganji, B.; Elahinia, M. On the crystallographic texture and torsional behavior of NiTi shape memory alloy processed by laser powder bed fusion: Effect of build orientation, *Additive Manufacturing* **2022**, Volume 59, Part B, Pages 103184-103201, doi: 10.1016/j.addma.2022.103184.
15. Sun, G.; Liu, H.; Liu, W.; Yang, W. Development, simulation, and validation of sliding self-centering steel brace with NiTi SMA wires, *Engineering Structures* **2022**, Volume 256, Pages 114069-114088, doi: 10.1016/j.engstruct.2022.114069.
16. Rao, Z.; Wang, X.; Leng, J.; Yan, Z.; Yan, X. Design methodology of the Ni50Ti50 shape memory alloy beam actuator: Heat treatment, training and numerical simulation, *Materials & Design* **2022**, Volume 217, Pages 110615-110630, doi: 10.1016/j.matdes.2022.110615.
17. Hau, C.T.; Gouwanda, D.; Gopalai, A.A.; Low, C.Y.; Hanapiah, F.A. Gamification and Control of Nitinol Based Ankle Rehabilitation Robot. *Biomimetics* **2022**, Volume 6, Pages 53-65, doi: 10.3390/biomimetics6030053.
18. Dumitru, C.; Milici, L.D.; Pentiu, R.D.; Atănașoae, P.; Ungureanu, C.; Hopulele, E. Experimental Analysis on the Impact of Current on the Strength and Lifespan of a Ni-Ti Element. *Appl. Sci.* **2022**, Volume 12, Pages 3185-3195, doi: 10.3390/app12063185.
19. Pu, Z.; Du, D.; Wang, K.; Liu, G.; Zhang, D.; Zhang, H.; Xi, R.; Wang, X.; Chang, B. Study on the NiTi shape memory alloys in-situ synthesized by dual-wire-feed electron beam additive manufacturing, *Additive Manufacturing* **2022**, Volume 56, Pages 102886-102900, doi: 10.1016/j.addma.2022.102886.
20. Wang, J.; Huang, B.; Gu, X.; Zhu, J.; Zhang, W. Actuation performance of machined helical springs from NiTi shape memory alloy, *International Journal of Mechanical Sciences* **2022**, Pages 107744-107755, doi: 10.1016/j.ijmecsci.2022.107744.
21. Zhang, Y.; Kang, G.; Miao, H.; Yu, C. Cyclic degeneration of elastocaloric effect for NiTi shape memory alloy: Experimental observation and constitutive model, *International Journal of Solids and Structures* **2022**, Volume 248, Pages 111638-111644, doi: 10.1016/j.ijsolstr.2022.111638.
22. Xiong, Z.; Li, H.; Yang, H.; Yang, Y.; Liu, Y.; Cui, L.; Li, X.; Masseling, L.; Shen, L.; Hao, S. Micro laser powder bed fusion of NiTi alloys with superior mechanical property and shape recovery function, *Additive Manufacturing* **2022**, Volume 57, Pages 102960-102972, doi: 10.1016/j.addma.2022.102960.
23. Li, X.; Cheng, S.; Sun, Q. A compact NiTi elastocaloric air cooler with low force bending actuation, *Applied Thermal Engineering* **2022**, Volume 215, Pages 118942-118951, doi: 10.1016/j.applthermaleng.2022.118942.
24. Lu, H.Z.; Ma, H.W.; Cai, W.S.; Luo, X.; Qu, S.G.; Wang, J.; Lupoi, R.; Yin, S.; Yang, C. Altered phase transformation behaviors and enhanced bending shape memory property of NiTi shape memory alloy via selective laser melting, *Journal of Materials Processing Technology* **2022**, Volume 303, Pages 117546-117558, doi: 10.1016/j.jmatprotec.2022.117546.
25. Gangwar, K.; Jayachandran, S.; Sahu, A.; Singh, A.; Palani, I.A. Influence of pre-strain on attributes of Ni-rich NiTi/ Kapton polyimide bimorph for flexible mirrors, *Sensors and Actuators A: Physical* **2022**, Volume 341, Pages 113607-113620, doi: 10.1016/j.sna.2022.113607.

26. Fazeli, S.; Izadifar, M.; Dolado, J.S.; Ramazani, A.; Sadrnezhad, S.K. Atomistic study of the effect of crystallographic orientation on the twinning and detwinning behavior of NiTi shape memory alloys, *Computational Materials Science* **2022**, Volume 203, Pages 111080-111096, doi: 10.1016/j.commatsci.2021.111080.
27. Maimani, F.; Calderón, A.A.; Yang, X.; Rigo, A.; Ge, J.Z.; Pérez-Arancibia, N.A. A 7-mg miniature catalytic-combustion engine for millimeter-scale robotic actuation, *Sensors and Actuators A: Physical* **2022**, Volume 341, Pages 112818-112828, doi: 10.1016/j.sna.2021.112818.
28. Rajoriya, S., Mishra, S.S. Size, length, temperature and loading range effects on deformation response of NiTi SMA wire: an analytical study. *Innov. Infrastruct. Solut.* **2022**, Volume 7, Pages 217-243, Doi: 10.1007/s41062-022-00814-y.
29. Han M. Jiang, Chao Yu, Qianhua Kan, Bo Xu, Chuanping Ma, Guozheng Kang, Effect of hydrogen on super-elastic behavior of NiTi shape memory alloy wires: Experimental observation and diffusional-mechanically coupled constitutive model, *Journal of the Mechanical Behavior of Biomedical Materials* **2022**, Volume 132, Pages 105276-105293, doi: 10.1016/j.jmbbm.2022.105276.
30. Zhang, Y.; Jiang, S.; Zhao, G.; Guo, K. Transformation yield surface of nanocrystalline NiTi shape memory alloy, *International Journal of Mechanical Sciences* **2022**, Volume 222, Pages 107258-107276, doi: 10.1016/j.ijmecsci.2022.107258.
31. Bhardwaj, A.; Ojha, M.; Garudapalli, A.; Gupta, A.K. Microstructural, mechanical and strain hardening behavior of NiTi alloy subjected to constrained groove pressing and ageing treatment, *Journal of Materials Processing Technology* **2021**, Volume 294, Pages 117132-117146, doi: 10.1016/j.jmatprotec.2021.117132.
32. McCue, I.D.; Valentino, G.M.; Trigg, D.B.; Lennon, A.M.; Hebert, C.E.; Seker, D.P.; Nimer, S.M.; Mastandrea, J.P.; Trexler, M.M. Storck, S.M. Controlled shape-morphing metallic components for deployable structures, *Materials & Design* **2021**, Volume 208, 2021, Pages 109935-109947, doi: 10.1016/j.matdes.2021.109935.
33. Singh, S.; Resnina, N.; Belyaev, S.; Jinoop, A.N.; Shukla, A.; Palani, I.A.; Paul, C.P.; Bindra, K.S. Investigations on NiTi shape memory alloy thin wall structures through laser marking assisted wire arc based additive manufacturing, *Journal of Manufacturing Processes* **2021**, Volume 66, 2021, Pages 70-80, doi: 10.1016/j.jmapro.2021.04.004.
34. Tyc, O.; Molnárová, O.; Šittner, P. Effect of microstructure on fatigue of superelastic NiTi wires, *International Journal of Fatigue* **2021**, Volume 152, 2021, Pages 106400-106414, doi: 10.1016/j.ijfatigue.2021.106400.
35. Liu, W.; Sun, G.; Chen, L.; Kong, J. Experimental investigation into NiTi shape memory alloy panels under cyclic shear loading, *Engineering Structures* **2021**, Volume 245, Pages 112958-112975, doi: 10.1016/j.engstruct.2021.112958.
36. Safaei, K.; Nematollahi, M.; Bayati, P.; Dabbaghi, H.; Benafan, O.; Elahinia, M. Torsional behavior and microstructure characterization of additively manufactured NiTi shape memory alloy tubes, *Engineering Structures* **2021**, Volume 226, Pages 111383-111392, doi: 10.1016/j.engstruct.2020.111383.
37. Shayanfard, P.; Heller, L.; Šandera, P.; Šittner, P. Numerical analysis of NiTi actuators with stress risers: The role of bias load and actuation temperature, *Engineering Fracture Mechanics* **2021**, Volume 244, Pages 107551-107562, doi: 10.1016/j.engfracmech.2021.107551.
38. Eyer, P.; Dittus, J.; Trauth, A.; Coutandin, S.; Fleischer, J.; Weidenmann, K.A. Improvement of the adhesion in functional NiTi wire/polymer composites made by additive manufacturing, *Composite Structures* **2021**, Volume 275, Pages 114455-114462, doi: 10.1016/j.compstruct.2021.114455.
39. Jape, S.; Young, B.; Haghgouyan, B.; Hayrettin, C.; Baxevanis, T.; Lagoudas, D.C.; Karaman, I. Actuation-Induced stable crack growth in near-equiatomic nickel-titanium shape memory alloys: Experimental and numerical analysis, *International Journal of Solids and Structures* **2021**, Volume 221, Pages 165-179, doi: 10.1016/j.ijsolstr.2020.09.032.
40. Oliveira, J.P.; Shen, J.; Escobar, J.D.; Salvador, C.A.F.; Schell, N.; Zhou, N.; Benafan, O. Laser welding of H-phase strengthened Ni-rich NiTi-20Zr high temperature shape memory alloy, *Materials & Design* **2021**, Volume 202, Pages 109533-109543, doi: 10.1016/j.matdes.2021.109533.

41. Karna, P.; Mani Prabu, S.S.; Karthikeyan, S.C.; Mithun, R.; Jayachandran, S.; Resnina, N.; Belyaev, S.; Palani, I.A. Investigations on laser actuation and life cycle characteristics of NiTi shape memory alloy bimorph for non-contact functional applications, *Sensors and Actuators A: Physical* **2021**, Volume 321, Pages 112411-112425, doi: 10.1016/j.sna.2020.112411.
42. Cissé, C.; Zaeem, M.A. Design of NiTi-based shape memory microcomposites with enhanced elastocaloric performance by a fully thermomechanical coupled phase-field model, *Materials & Design* **2021**, Volume 207, Pages 109898-109909, doi: 10.1016/j.matdes.2021.109898.
43. Ko, W.S.; Jeon, J.B. Atomistic simulations on orientation dependent martensitic transformation during nanoindentation of NiTi shape-memory alloys, *Computational Materials Science* **2021**, Volume 187, Pages 110127-110135, doi: 10.1016/j.commatsci.2020.110127.
44. Sedlák, P.; Frost, M.; Ševčík, M.; H. Seiner, M. 3D spatial reconstruction of macroscopic austenite-martensite transition zones in NiTi wires induced by tension and twisting using diffraction/scattering computed tomography, *International Journal of Solids and Structures* **2021**, Volume 228, Pages 111122-111137, doi: 10.1016/j.ijsolstr.2021.111122.
45. Yang, Y.; Wu, Z.G.; Shen, B.Y.; Wu, M.Z.; Yuan, Z.S.; Wang, C.Y.; Zhang, L.C. Graded functionality obtained in NiTi shape memory alloy via a repetitive laser processing strategy, *Journal of Materials Processing Technology* **2021**, Volume 296, Pages 117177-117192, doi: 10.1016/j.jmatprotec.2021.117177.
46. Liu, S.; Lin, Y.; Han, L.; Wang, X.; Zhao, G.; Wang, G. Atomistic simulation of microstructure evolution of NiTi single crystals in bending deformation, *Computational Materials Science* **2021**, Volume 199, Pages 110733-11747, doi: 10.1016/j.commatsci.2021.110733.
47. Guo, S.; Wu, T.; Kwak, M.; Lu, W.; Ma, W.; Liu, Q.; Liu, H.; Meng, Q.; Liu, G.; Cheng, X.; Zhao, X. Achieving a combination of decent biocompatibility and large near-linear-elastic deformation behavior in shell-core-like structural TiNb/NiTi composite, *Journal of the Mechanical Behavior of Biomedical Materials* **2021**, Volume 123, Pages 104789-104798, doi: 10.1016/j.jmbbm.2021.104789.
48. Islam, Md.M.; Bayati, P.; Nematollahi, M.; Jahadakbar, A.; Elahinia, M.; Haghshenas, M. Strain rate dependent micromechanical properties of NiTi shape memory alloys: Laser powder bed fusion versus casting, *Forces in Mechanics* **2021**, Volume 5, Pages 100055-100062, doi: 10.1016/j.finmec.2021.100055.
49. Mehrpouya, M.; Gisario, A.; Lavvafi, H.; Dehghanghadikolaei, Darafsheh, A. Chapter 8 - Laser welding of nickel-titanium (NiTi) shape memory alloys, Editor(s): J. Paulo Davim, Kapil Gupta, Kapil Gupta, J. Paulo Davim, In *Handbooks in Advanced Manufacturing, Advanced Welding and Deforming* **2021**, Elsevier, Pages 203-230, doi: 10.1016/B978-0-12-822049-8.00008-6.
50. Lv, C.; Wang, G.; Zhang, X.; Luo, B.; Luo, N.; Wu, F.; Wu, H.; Tan, F.; Zhao, J.; Liu, C.; Sun, C. Spalling modes and mechanisms of shocked nanocrystalline NiTi at different loadings and temperatures, *Mechanics of Materials* **2021**, Volume 161, Pages 104004-104015, doi: 10.1016/j.mechmat.2021.104004.
51. Owusu-Danquah, J.S.; Saleeb, A.F.; Soudah, M.A. Cyclic pseudoelastic training and two-way shape memory behavior of a NiTi alloy with small irrecoverable plastic strains: numerical modeling, *International Journal of Solids and Structures* **2021**, Volumes 217–218, Pages 178-192, doi: 10.1016/j.ijsolstr.2021.02.005.
52. Varughese, K.; El-Hacha, R. Experimental free vibrations test of steel braced frames reinforced with NiTi shape memory alloy wires, *Structures* **2021**, Volume 29, Pages 1165-1172, doi: 10.1016/j.istruc.2020.11.022.
53. Guo, S.; Zhang, H.; Chen, Y.; Liu, Q.; Wu, R.; Ma, W.; Liu, H.; Meng, Q.; Liu, G.; Cheng, X.; Zhao, X. A sandwich-structured Nb/NiTi composite with good bio-compatibility, near-linear-elastic deformation and large elastic admissible strain, *Composites Part B: Engineering* **2021**, Volume 207, Pages 108586-108593, doi: 10.1016/j.compositesb.2020.108586.
54. Marandi, L.; Sen, I. In-vitro mechanical behavior and high cycle fatigue characteristics of NiTi-based shape memory alloy wire, *International Journal of Fatigue* **2021**, Volume 148, Pages 106226-106239, doi: 10.1016/j.ijfatigue.2021.106226.
55. Khan, S.; Pydi, Y.S.; Prabu, M.; Palani, I.A.; Singh, P. Development and actuation analysis of shape memory alloy reinforced composite fin for aerodynamic application, *Sensors and Actuators A: Physical* **2021**, Volume 331, Pages 113012-113021, doi: 10.1016/j.sna.2021.113012.

56. Sibirev, A.; Belyaev, S.; Resnina, N. The influence of counter-body stiffness on working parameters of NiTi actuator, *Sensors and Actuators A: Physical* **2021**, Volume 319, Pages 112568-112573, doi: 10.1016/j.sna.2021.112568.
57. LePage, W.S.; Shaw, J.A.; Daly, S.H. Effects of texture on the functional and structural fatigue of a NiTi shape memory alloy, *International Journal of Solids and Structures* **2021**, Volume 221, Pages 150-164, doi: 10.1016/j.ijsolstr.2020.09.022.
58. Chen, J.; Fang, C.; Wang, W.; Liu, Y. Variable-friction self-centering energy-dissipation braces (VF-SCEDBs) with NiTi SMA cables for seismic resilience, *Journal of Constructional Steel Research* **2020**, Volume 175, Pages 106318-106333, doi: 10.1016/j.jcsr.2020.106318.
59. Cavaleiro, A.J.; Ramos, A.S.; Braz Fernandes, F.M.; Schell, N.; Vieira, M.T. Follow-up structural evolution of Ni/Ti reactive nano and microlayers during diffusion bonding of NiTi to Ti6Al4V in a synchrotron beamline, *Journal of Materials Processing Technology*, Volume 275, **2020**, Pages 116354-116381, doi: 10.1016/j.jmatprotec.2019.116354.
60. Zhao, W.; Lin, P.; Lin, T.; He, P.; Liu, Y.; Long, W.; Li, J. Low temperature joining of NiTi shape memory alloy with Au-Si isothermal solidification, *Journal of Manufacturing Processes* **2020**, Volume 58, Pages 1034-1038, doi: 10.1016/j.jmapro.2020.09.007.
61. Yang, Z.; Wang, H.; Huang, y.; Ye, X.; Li, J.; Zhang, C.; Li, H.; Pang, B.; Tian, Y.; Huang, C.; Sun, G. Strain rate dependent mechanical response for monoclinic NiTi shape memory alloy: Micromechanical decomposition and model validation via neutron diffraction, *Materials & Design* **2020**, Volume 191, Pages 108656 - 108671, doi: 10.1016/j.matdes.2020.108656.
62. Zhou, T.; Yu, C.; Kang, G.; Kan, Q.; Fang, D. A crystal plasticity based constitutive model accounting for R phase and two-step phase transition of polycrystalline NiTi shape memory alloys, *International Journal of Solids and Structures* **2020**, Volumes 193–194, Pages 503-526, doi: 10.1016/j.ijsolstr.2020.03.001.
63. Varughese, K.; El-Hacha, R. Design and behaviour of steel braced frame reinforced with NiTi SMA wires, *Engineering Structures* **2020**, Volume 212, Pages 110502-110511, doi: 10.1016/j.engstruct.2020.110502.
64. Xie, X.; Kang, G.; Kan, Q.; Yu, C. Phase-field theory based finite element simulation on thermo-mechanical cyclic deformation of polycrystalline super-elastic NiTi shape memory alloy, *Computational Materials Science* **2020**, Volume 184, Pages 109899-109914, doi: 10.1016/j.commatsci.2020.109899.
65. Wang, X.; Yu, J.; Liu, J.; Chen, L.; Yang, Q.; Wei, H.; Sun, J.; Wang, Z.; Zhang, Z.; Zhao, G.; Van Humbeek, J. Effect of process parameters on the phase transformation behavior and tensile properties of NiTi shape memory alloys fabricated by selective laser melting, *Additive Manufacturing* **2020**, Volume 36, Pages 101545-101559, doi: 10.1016/j.addma.2020.101545.
66. Lu, B.; Cui, X.; Jin, G.; Dong, M.; Fang, Y.; Wen, X.; Ma, W. Effect of La<sub>2</sub>O<sub>3</sub> addition on mechanical properties and wear behavior of NiTi alloy fabricated by direct metal deposition, *Optics & Laser Technology* **2020**, Volume 129, Pages 106290-106299, doi: 10.1016/j.optlastec.2020.106290.
67. Fu, J.; Hu, Z.; Song, X.; Zhai, W.; Long, Y.; Li, H.; Fu, M. Micro selective laser melting of NiTi shape memory alloy: Defects, microstructures and thermal/mechanical properties, *Optics & Laser Technology* **2020**, Volume 131, Pages 106374-106385, doi: 10.1016/j.optlastec.2020.106374.
68. Ao, S.; Li, K.; Liu, W.; Qin, W.; Wang, T.; Dai, Y.; Luo, Z. Electrochemical micromachining of NiTi shape memory alloy with ethylene glycol–NaCl electrolyte containing ethanol, *Journal of Manufacturing Processes* **2020**, Volume 53, Pages 223-228, doi: 10.1016/j.jmapro.2020.02.019.
69. Belyaev, S.; Resnina, N.; Rakhimov, T.; Andreev, V. Martensite stabilization effect in Ni-rich NiTi shape memory alloy with different structure and martensitic transformations, *Sensors and Actuators A: Physical* **2020**, Volume 305, Pages 111911-111932, doi: 10.1016/j.sna.2020.111911.
70. Askari-Naeini, F.G.; Taghizadeh, M.; Mohri, M.; Nili-Ahmadabadi, M. On the microstructure and mechanical properties of a two-way shape memory NiTi/NiTiCu bi-layer diaphragm, *Materials & Design* **2020**, Volume 188, Pages 108464-108485, doi: 10.1016/j.matdes.2019.108464.
71. Racek, J.; Šittner, P. Environmental fatigue of superelastic NiTi wire with two surface finishes, *Journal of the Mechanical Behavior of Biomedical Materials* **2020**, Volume 111, Pages 104028-104064, doi: 10.1016/j.jmbbm.2020.104028.

72. Ruvinov, I.; Zamani, N.; Zhou, N.Y.; Khan, M.Y. Novel laser processed shape memory alloy actuator design with an embedded strain gauge sensor using dual resistance measurements. Part II: Recurrent neural network-based position and force estimation, *Sensors and Actuators A: Physical* **2020**, Volume 313, Pages 112188, doi: 10.1016/j.sna.2020.112188.
73. Freitas Rodrigues, P.; Braz Fernandes, F.M.; Magalhães, R.; Camacho, E.; Lopes, A.; Paula, A.S.; Basu, R.; Schell, N. Thermo-mechanical characterization of NiTi orthodontic archwires with graded actuating forces, *Journal of the Mechanical Behavior of Biomedical Materials* **2020**, Volume 107, Pages 103747-103754, doi: 10.1016/j.jmbbm.2020.103747.
74. Reis Barros, C.D.; Cunha Ponciano Gomes, J.A. Strain induced localized corrosion of NiTi, NiTiCo and NiTiCr alloys in 0.9% NaCl, *Journal of the Mechanical Behavior of Biomedical Materials* **2020**, Volume 112, Pages 104015-104043, doi: 10.1016/j.jmbbm.2020.104015.
75. Zhao, Y.; Li, J.; Guo, K.; Sivalingam, V.; Sun, J. Study on chip formation characteristics in turning NiTi shape memory alloys, *Journal of Manufacturing Processes* **2020**, Volume 58, Pages 787-795, doi: 10.1016/j.jmapro.2020.08.072.
76. Polatidis, E.; Šmíd, M.; Kuběna, I.; Hsu, W.N.; Laplanche, G.; Van Swygenhoven, H. Deformation mechanisms in a superelastic NiTi alloy: An in-situ high resolution digital image correlation study, *Materials & Design* **2020**, Volume 191, Pages 108622-108632, doi: 10.1016/j.matdes.2020.108622.
77. Ebrahimi, P.; Arghavani, Naghdabadi, R.; McGarry, J.P. On the effect of detwinning-induced plasticity in compressive cyclic loading of NiTi shape memory alloys, *Mechanics of Materials* **2020**, Volume 148, Pages 103451-103494, doi: 10.1016/j.mechmat.2020.103451.
78. Zeng, Z.; Oliveira, J.P.; Ao, S.; Zhang, W.; Cui, J.; Yan, S.; Peng, B. Fabrication and characterization of a novel bionic manipulator using a laser processed NiTi shape memory alloy, *Optics & Laser Technology* **2020**, Volume 122, Pages 105876-105882, doi: 10.1016/j.optlastec.2019.105876.
79. Schuleit, M.; Theren, B.; Maack, P.; Kuhlenkötter, B.; Esen, C. Investigation of minimal strokes of NiTi shape memory wires using laser activation, *Procedia CIRP* **2020**, Volume 94, 2020, Pages 542-545, doi: 10.1016/j.procir.2020.09.179.
80. Kaya, E.; Kaya, İ. Tool wear progression of PCD and PCBN cutting tools in high speed machining of NiTi shape memory alloy under various cutting speeds, *Diamond and Related Materials* **2020**, Volume 105, Pages 107810-107820, doi: 10.1016/j.diamond.2020.107810.
81. Schuleit, M.; Becher, M.; Franke, F.; Maaß, B.; Esen, C. Development of form-fit connection for NiTi shape memory wire actuators using laser processing, *Procedia CIRP* **2020**, Volume 94, Pages 546-550, doi: 10.1016/j.procir.2020.09.180.
82. Mingear, J.; Zhang, B.; Hartl, D.; Elwany, A. Effect of process parameters and electropolishing on the surface roughness of interior channels in additively manufactured nickel-titanium shape memory alloy actuators, *Additive Manufacturing* **2019**, Volume 27, Pages 565-575, doi: 10.1016/j.addma.2019.03.027.
83. Es-Souni, M.; Wassel, E.; Dietze, M.; Laghrissi, A.; Klöhn, F.; Weyrich, T.; Es-Souni, M. Processing of nanotubes on NiTi-shape memory alloys and their modification with photografted anti-adhesive polymer brushes. Towards smart implant surfaces, *Materials & Design* **2019**, Volume 182, Pages 108031-108042, doi: 10.1016/j.matdes.2019.108031.
84. Lin, H.C.; Chang, Y.L.; Han, Y.Y.; Yang, K.C.; Chen, M.K. Atomic Layer Deposited Al<sub>2</sub>O<sub>3</sub> Films on NiTi Shape Memory Alloys for Biomedical Applications, *Procedia Manufacturing* **2019**, Volume 37, Pages 431-437, doi: 10.1016/j.promfg.2019.12.070.
85. Tsouknidas A., Michailidis N., Maliaris G., Makkar J., Baxevanis Th., Lagoudas D., A numerical study of "functional fatigue" of closed-cell NiTi shape memory foams, *Mechanics of Materials* **2019**, Volume 131, Pages 11-21, doi: 10.1016/j.mechmat.2019.01.003.
86. Dhala, S.; Mishra, S.; Tewari, A.; Alankar, A. Modeling of finite deformation of pseudoelastic NiTi shape memory alloy considering various inelasticity mechanisms, *International Journal of Plasticity* **2019**, Volume 115, Pages 216-237, doi: 10.1016/j.ijplas.2018.11.018.

87. Jayachandran, S.; Akash, K.; Mani Prabu, S.S.; Manikandan, M.; Muralidharan, M.; Brodin, A.; Palani, I.A. Investigations on performance viability of NiTi, NiTiCu, CuAlNi and CuAlNiMn shape memory alloy/Kapton composite thin film for actuator application, *Composites Part B: Engineering* **2019**, Volume 176, Pages 107182-107205, doi: 10.1016/j.compositesb.2019.107182.
88. Li, X.; Chen, X.; Zhang, C.; Luo, J. Preparation of self-lubricating NiTi alloy and its self-adaptive behavior, *Tribology International* **2019**, Volume 130, Pages 43-51, doi: 10.1016/j.triboint.2018.09.002.
89. Zhang, X.; Wei, L. Processing and damping capacity of NiTi foams with laminated pore architecture, *Journal of the Mechanical Behavior of Biomedical Materials* **2019**, Volume 96, Pages 108-117, doi: 10.1016/j.jmbbm.2019.04.036.
90. Boschetto, A.; Bottini, L.; Costanza, G.; Tata, M.E. Shape Memory Activated Self-Deployable Solar Sails: Small-Scale Prototypes Manufacturing and Planarity Analysis by 3D Laser Scanner. *Actuators* **2019**, Volume 8, Pages 38-48, doi: 10.3390/act8020038.
91. Chen, L.; Li, Y.; Xiao, B.; Zheng, O.; Gao, Y.; Zhao, S.; Wang, Z. First-principles calculation on the adhesion strength, fracture mechanism, interfacial bonding of the NiTi (111)// $\alpha$ -Al<sub>2</sub>O<sub>3</sub> (0001) interfaces, *Materials & Design* **2019**, Volume 183, Pages 108119-108133, doi: 10.1016/j.matdes.2019.108119.
92. Panton, B.; Michael, A.; Zhou, Y.N.; Khan, M.Y. Effects of post-processing on the thermomechanical fatigue properties of laser modified NiTi, *International Journal of Fatigue* **2019**, Volume 118, Pages 307-315, doi: 10.1016/j.ijfatigue.2017.11.012.
93. Lesota, A.; Sibirev, A.; Rubanik, V.; Rubanik, V.; Resnina, N.; Belyaev, S. Initiation of the shape memory effect by temperature variation or ultrasonic vibrations in the NiTi shape memory alloy after different preliminary deformation, *Sensors and Actuators A: Physical* **2019**, Volume 286, Pages 1-3, doi: 10.1016/j.sna.2018.12.016.
94. Chen, Y.; Tyc, O.; Kadeřávek, L.; Molnárová, O.; Heller, L.; Šittner, P. Temperature and microstructure dependence of localized tensile deformation of superelastic NiTi wires, *Materials & Design* **2019**, Volume 174, Pages 107797-107851, doi: 10.1016/j.matdes.2019.107797.
95. Knick, C.R.; Smith, G.L.; Morris, C.J.; Bruck, H.A. Rapid and low power laser actuation of sputter-deposited NiTi shape memory alloy (SMA) MEMS thermal bimorph actuators, *Sensors and Actuators A: Physical* **2019**, Volume 291, Pages 48-57, doi: 10.1016/j.sna.2019.03.016.
96. Heller, L.; Šittner, P.; Sedlák, P.; Seiner, H.; Tyc, O.; Kadeřávek, L.; Sedmák, P.; Vronka, M. Beyond the strain recoverability of martensitic transformation in NiTi, *International Journal of Plasticity* **2019**, Volume 116, Pages 232-264, doi: 10.1016/j.ijplas.2019.01.007.
97. Fazeli, S.; Sadmezzaad, S.K. Molecular dynamics simulation of plastic deformation and interfacial delamination of NiTi/Ag bilayer by cyclic-nanoindentation: Effects of crystallographic orientation of substrate, *Computational Materials Science* **2019**, Volume 168, Pages 229-245, doi: 10.1016/j.commatsci.2019.05.032.
98. Ponikarova, I.; Belyaev, S.; Resnina, N. Degradation of two-way shape memory effect due to the relaxation of internal oriented stress in NiTi alloy on holding at 640÷700 K, *Mechanics of Materials* **2019**, Volume 138, Pages 103174-103179, doi: 10.1016/j.mechmat.2019.103174.
99. Ainslie, K.; Knick, C.; Smith, G.; Li, J.; Troxel, C.; Mehta, A.; Kukreja, R. Controlling shape memory effects in NiTi thin films grown on Ru seed layer, *Sensors and Actuators A: Physical* **2019**, Volume 294, Pages 133-139, doi: 10.1016/j.sna.2019.04.047.
100. Gédouin, P.A.; Pino, L.; Chirani, S.A.; Calloch, S.; Delaleau, E.; Bourgeot, M.J. R-phase shape memory alloy helical spring based actuators: Modeling and experiments, *Sensors and Actuators A: Physical* **2019**, Volume 289, Pages 65-76, doi: 10.1016/j.sna.2019.02.024.
101. Mani Prabu, S.S.; Perugu, C.S.; Madhu, H.C.; Jangde, A.; Khan, S.; Jayachandran, S.; Manikandan, M.; Ajay Kumar, P.; Kailas, S.V.; Palani, I.A. Exploring the functional and corrosion behavior of friction stir welded NiTi shape memory alloy, *Journal of Manufacturing Processes* **2019**, Volume 47, Pages 119-128, doi: 10.1016/j.jmapro.2019.09.017.
102. Cernușcă, D.; Milici, D.L.; Poienar, M. "Development of special actuators using smart materials," 2016 *International Conference and Exposition on Electrical and Power Engineering (EPE)* **2018**, Pages 567-570, doi: 10.1109/ICEPE.2016.7781404.

103. Lee, K.J.; Lee, J.H.; Jung, C.Y.; Choi, E. Crack-closing performance of NiTi and NiTiNb fibers in cement mortar beams using shape memory effects, *Composite Structures* **2018**, Volume 202, Pages 710-718, doi: 10.1016/j.compstruct.2018.03.080.
104. Mehrpouya, M.; Gisario, A.; Elahinia, M. Laser welding of NiTi shape memory alloy: A review, *Journal of Manufacturing Processes* **2018**, Volume 31, Pages 162-186, doi: 10.1016/j.jmapro.2017.11.011.
105. Ammar, O.; Dieng, L.; Haddar, N. Modeling of strain rate effect on the pseudoelastic behavior of NiTi SMA using a simple thermomechanical coupling model, *Mechanics of Materials* **2018**, Volume 124, Pages 7-17, doi: 10.1016/j.mechmat.2018.05.004.
106. Mehrpouya, M.; Gisario, A.; Brotzu, A.; Natali, S. Laser welding of NiTi shape memory sheets using a diode laser, *Optics & Laser Technology* **2018**, Volume 108, Pages 142-149, doi: 10.1016/j.optlastec.2018.06.038.
107. Solomou, A.; Zhao, G.; Boluki, S.; Joy, J.K.; Qian, X.; Karaman, I.; Arróyave, R.; Lagoudas, D.C. Multi-objective Bayesian materials discovery: Application on the discovery of precipitation strengthened NiTi shape memory alloys through micromechanical modeling, *Materials & Design* **2018**, Volume 160, Pages 810-827, doi: 10.1016/j.matdes.2018.10.014.
108. Toader, V.E.; Milici, L.D.; Ungureanu, C.; Bejenar, C.; Grosu, O.V. Analysis of a Low-Speed Drive System Using Intelligent Materials. *Actuators* **2022**, Volume 11, Pages 10-31, doi: 10.3390/act11010010.
109. Toader, V.E.; Poienar, M.; Cernușcă, D.; Study of smart materials used in the development of new types of electro and thermomechanical actuators, *Conferința tehnico-științifică a studenților, masteranzilor și doctoranzilor* **2019**, Pages 134-137, Moldova.
110. Romanescu, A.N.; Poienar, M.; Cenușă, M.; Nițan, I. Performance analysis of a linear heliothermic actuator, *International Conference on Modern Power Systems (MPS)* **2017**, Pages 1-4, doi: 10.1109/MPS.2017.7974424.
111. Cernușcă, D.; Milici D.L.; Poienar, M. Researches on the Realization of a Electromechanical Micropump, 2018 *International Conference and Exposition on Electrical and Power Engineering (EPE)* **2018**, Pages 0270-0273, doi: 10.1109/ICEPE.2018.8559774.
112. Cernușcă, D.; Milici D.L.; Ungureanu, C. Theoretical and experimental contribution of using special actuators and materials with shape memory, 2016 *International Conference and Exposition on Electrical and Power Engineering (EPE)* **2016**, Pages 171-174, doi: 10.1109/ICEPE.2016.7781327.
113. Cernușcă, D.; Milici, D.L.; Pentiuc, R.D.; Hopulele, E. Research on the Realization of a Nitinol Clutch Type Thermocouple," 2020 *International Conference and Exposition on Electrical and Power Engineering (EPE)* **2020**, Pages 078-081, doi:10.1109/EPE50722.2020.9305631.
114. Toader, V.E.; Bejenar, C.; Paval, M.; Cernușcă D.; Grosu, O.V. Considerations Regarding a Nitinol (Ni-Ti)-operated Micropump," 2021 *International Conference on Applied and Theoretical Electricity (ICATE)* **2021**, Pages 1-4, doi: 10.1109/ICATE49685.2021.9464982.
115. Cernușcă, D.; Milici, D.L.; Pavăl, M.; Hopulele, E.; Toader, E.V.; Cernușcă, P. Design, Implementation and Testing of a Locking System, 2021 *International Conference on Applied and Theoretical Electricity (ICATE)* **2021**, Pages 1-4, doi: 10.1109/ICATE49685.2021.9464992.
116. Wu, Z.; Liu, B.; Wei, J.; Yang, Y.; Zhang, X.; Deng, J. Design of Porous Shape Memory Alloys with Small Mechanical Hysteresis. *Crystals* **2023**, 13, 34. <https://doi.org/10.3390/cryst13010034>
117. Khan, LA; McCarthy, E; Muilwijk, C; Ul Ahad, I; Brabazon, D. Analysis of nitinol actuator response under controlled conductiv heating regimes, *Results in engineering* **2023**, 18, doi: 10.1016/j.rineng.2023.101047.
118. Sibirev, A.V.; Belyaev, S.P.; Resnina, N.N. Influence of temperature range on NiTi SMA actuator performance during thermal cycling, *Material Science* **2023**, 13, 3, doi: 10.22226/2410-3535-2023-3-249-254.
119. Singh, S.; Palani, I.A.; Dehgahi, S.; Paul, C.P.; Prashanth, K.G.; Qureshi, A.J. Influence of the interlayer temperature on structure and properties of CMT wire arc additive manufactured NiTi structures, *Journal of alloys and compounds* **2023**, 966, doi: 10.1016/j.jallcom.2023.171447.
120. Sibirev, A.; Belyaev, S.; Resnina, N. Improvement of the NiTi actuator performance stability by decreasing its operating temperature range, *Sensors and actuators a-physical* **2023**, 363, doi: 10.1016/j.sna.2023.114743.
121. Fuaad, M.R.A.; Hasan, M.N.; Asri, M.I.A.; Ali, M.S.M. Microactuators technologies for biomedical applications, *Microsystem technologies-micro-and nanosystems-information storage and processing systems* **2023**, 29 (7), doi: 10.1007/s00542-023-05489-8.

122. Chen, P.; Liu, Y.F.; Min, N.; Wang, M.M.; Cai, X.R.; Jin, M.J.; Jin, X.J. Enhanced two way shape memory effect in nanocrystalline NiTi shape memory alloy wires, *Scripta Materialia*, Volume 236, **2023**, 115669, doi: 10.1016/j.scriptamat.2023.115669.
123. Sukjun, K.; Bergbreiter, S. "3D-Printed Adaptive Microgripper Driven by Thin-Film NiTi Actuators," *IEEE International Conference on Robotics and Automation (ICRA)*, London, United Kingdom, **2023**, pp. 5445-5451, doi: 10.1109/ICRA48891.2023.10160829.
124. Nicholson, D.E.; Benafan, O.; Bigelow, G.S.; Pick, D.; Demblon, A.; Mabe, J.H.; Karaman, I.; Van Doren, B.; Forbes, D.; Sczerzenie, F.; Fumagalli, L.; Wallner, C. Standardization of Shape Memory Alloys from Material to Actuator. *Shape memory and superelasticity*, **2023**, doi: 10.1007/s40830-023-00431-3.
125. Hartwich, J.; Slawski, S.; Kciuk, M.; Duda, S. Determination of Thin NiTi Wires' Mechanical Properties during Phase Transformations. *Sensors* **2023**, 23 (3), doi: 10.3390/s23031153.
126. Sibirev, A.V.; Belyaev, S.P.; Resnina, N.N. Influence of temperature range on NiTi SMA actuator performance during thermal cycling. *Letters on materials* **2023**, 13(3), doi: 10.22226/2410-3535-2023-3-249-254.
127. Thüsing, K.; Hofer, A.; Pagel, K.; Weck, C.; Drossel, W.G.H load NiTi shape memory alloy actuators: a study of cyclic behavior, *Proceedings of ASME 2023 conference on smart materials, adaptive, structures and intelligent systems*, **2023**, WOS:001216926200023.
128. Muniraj, L.; Ardron, M.; Reuben, R.L.; Hand, D.P. Laser-Induced Forward Transfer of Ni-rich NiTi Alloys for Shape Memory Applications, *Journal of Laser Micro Nanoengineering* **2023**, 18(2), doi: 10.2961/jlmn.2023.02.2007.
129. Shukla, S.; Barjibhe, R. Experimental and numerical Comparison of traditional spring DVA and shape memory alloy actuated DVA for fixed beam vibration control, *Materials Today: Proceedings*, **2023**, doi: 10.1016/j.matpr.2023.02.173.
130. Li, C.; Zhang, L.; Zhang, X.; Liu, G.; Zhao, J. A compliant actuator for steering the needle within tissue with feedback of FBG-based shape sensing, *Sensors and Actuators A: Physical*, Volume 356, **2023**, 114340, doi: 10.1016/j.sna.2023.114340.
131. Oguntosin, V. Design of a color changing shape memory actuator, *Science Talks*, Volume 5, **2023**, 100148, doi: 10.1016/j.sctalk.2023.100148.
132. Dang, P.; Zhou, Y.; Pang, J.; Ding, X.; Sun, J.; Lookman, T.; Xue, D. Achieving stable actuation response and elastocaloric effect in a nanocrystalline Ti50Ni40Cu10 alloy, *Scripta Materialia*, Volume 226, **2023**, 115263, doi: 10.1016/j.scriptamat.2022.115263.
133. Liu, Q.; Ghodrat, S.; Huisman, G.; Jansen, K.M.B. Shape memory alloy actuators for haptic wearables: A review, *Materials & Design*, Volume 233, **2023**, 112264, doi: 10.1016/j.matdes.2023.112264.
134. Kennedy, S.; Shougat, M.R.; Perkins, E. Robust self-sensing shape memory alloy actuator using a machine learning approach, *Sensors and Actuators A: Physical*, Volume 354, **2023**, 114255, doi: 10.1016/j.sna.2023.114255.
135. Shukla, S.; Barjibhe, R. An experimental and numerical comparison of traditional spring DVA in parallel and shape memory alloy actuated DVA in series and parallel for fixed beam vibration control, *Materials Today: Proceedings*, **2023**, doi: 10.1016/j.matpr.2023.04.615.
136. Durante, F.; Raparelli, T.; Zobel, P.B. Three-Degree-of-Freedom Cable-Driven Parallel Manipulator with Self-Sensing Nitinol Actuators. *Robotics* **2024**, 13(6), doi: 10.3390/robotics13060093.
137. Islam, M.N.; Gonzalez, M.B.; Tabassum, S.; Billah, K.M.M. "3D Printed Shape Memory Alloy Wire Embedded Actuator," *IEEE 17th Dallas Circuits and Systems Conference (DCAS)*, Richardson, TX, USA, **2024**, pp. 1-5, doi: 10.1109/DCAS61159.2024.10539916.
138. Hedrick, A.; Kabutz, H.; Smith, L.; MacCurdy R.; Jayaram, K. "Femtosecond Laser Fabricated Nitinol Living Hinges for Millimeter-Sized Robots," in *IEEE Robotics and Automation Letters*, vol. 9, no. 6, pp. 5449-5455, June **2024**, doi: 10.1109/LRA.2024.3392490.
139. Zuo Z.; He, X.; Wang, H.; Shao, Z.; Liu, J.; Zhang, Q. "A Nitinol-Embedded Wearable Soft Robotic Gripper for Deep-Sea Manipulation: A Wearable Device for Deep-Sea Delicate Operation," in *IEEE Robotics & Automation Magazine*, vol. 31, no. 1, pp. 96-107, March **2024**, doi: 10.1109/MRA.2024.3351477.

140. Satpute, S.N.; Sake, S.A.; Sardesai, P.P.; Sawant, P.S.; Sarode, A.V.; Sadegaonkar, V.G. "Nitinol Based heat Engine for Solar Energy Harvesting," *IEEE 19th International Conference on the Perspective Technologies and Methods in MEMS Design (MEMSTECH)*, Zozuli, Ukraine, **2024**, pp. 97-101, doi: 10.1109/MEMSTECH63437.2024.10620051.
141. Ryu, C.; Mani Prabu, S.S.; Palani, I.A.; Nguyen, A.P.; In, J.B. Improving the actuation behavior of nitinol shape memory alloys by nanosecond laser surface texturing, *Optics & Laser Technology*, Volume 176, **2024**, 110957, doi: 10.1016/j.optlastec.2024.110957.
142. Liu, Q.; Ghodrat, S.; Jansen, K.M.B. Design and modelling of a reversible shape memory alloy torsion hinge actuator, *Materials & Design*, Volume 237, **2024**, 112590, doi: 10.1016/j.matdes.2023.112590.
143. Pathan, M.; Devaramani, R.; Adinarayanappa, S.A. Modelling, simulation, and experiments of 4D printed twisting actuator, *Materials Today: Proceedings*, Volume 101, **2024**, Pages 43-50, doi: 10.1016/j.matpr.2023.03.004.
144. Fischer, M.; Santoro, L.A.; Bruk, S.; Henkel, K.; Hüttner, R.; Körbitz, R.; Brinkmann, F.; Spickenheuer, A.; Kühnert, I.; Hampe, J.; Uhlig, K. Friction testing of tube-guided electrically heated Nitinol shape-memory alloy wires, *Tribology International*, Volume 191, **2024**, 109161, doi: 10.1016/j.triboint.2023.109161.
145. Copaci, D.; Palenzuela, A.L.; Moreno, L.; Martínez, S.; Balaguer, C. Characterization and control of Shape Memory Alloy-based actuators for heavy payloads displacement, *Results in Engineering*, Volume 24, **2024**, 103387, doi: 10.1016/j.rineng.2024.103387.
146. Rosas Almeida, D.I.; Moreno Rodríguez, L.F. Experimental oscillation and regulation control strategy for 1-DOF mechanical rotational systems with an antagonistic SMA actuator, *Results in Engineering*, Volume 23, **2024**, 102559, doi: 10.1016/j.rineng.2024.102559.
147. Zuñiga, S.; Bravo, D.; Rengifo, C. Design and construction of a servomechanism using a memory alloy linear actuator, *HardwareX*, Volume 20, **2024**, e00587, doi: 10.1016/j.ohx.2024.e00587.
148. Shihora, N.; Simaan, N. The friction-limited end-effector motion resolution of tendon-actuated and continuum robots, *Mechanism and Machine Theory*, Volume 203, **2024**, 105814, doi: 10.1016/j.mechmachtheory.2024.105814.
149. Boni, C.; Galuppi, L. A kinematics-based single-actuator setup for constant-curvature bending tests in extremely large deformations, *Extreme Mechanics Letters*, Volume 73, **2024**, 102259, doi: 10.1016/j.eml.2024.102259.
150. Bertolini, R.; Khademzadeh, S.; Ghiotti, A.; Bruschi, S. Machining Effect on The Surface Integrity and SE Of Additively Manufactured And Heat-Treated Nitinol, *Procedia CIRP*, Volume 123, **2024**, Pages 47-52, doi: 10.1016/j.procir.2024.05.011.
151. Rodinò, S.; Maletta, C. Design considerations and applications of shape memory alloy-based actuation in morphing structures: A systematic review, *Progress in Engineering Science*, Volume 1, Issue 4, **2024**, 100021, doi: 10.1016/j.pes.2024.100021.
152. Singh, A.J.; Wala, S.; Ladakhan, S.H.; Sreesha, R.B.; Adinarayanappa, S.M. Design and fabrication of shape memory alloy based 4D-printed actuator for FWMAV: A performance study, *Materials Today: Proceedings*, Volume 101, **2024**, Pages 22-29, doi: 10.1016/j.matpr.2023.02.160.
153. Wei, L.J.; Ma, D.L.; Xie, D.; Jing, P.P.; Leng, Y.X. The performance and stability of NiTi photoactuator utilizing photothermal effect of TiN films with tilted columnar structure, *Sensors and Actuators A: Physical*, Volume 368, **2024**, 115106, doi: 10.1016/j.sna.2024.115106.
154. Dzugbewu, T.C.; Beer, D.J. Additive manufacturing of NiTi shape memory alloy and its industrial applications, *Heliyon*, Volume 10, Issue 1, **2024**, e23369, doi: 10.1016/j.heliyon.2023.e23369.
155. Leal, M.L.; Pino, L.; Barati, M.; Saint-Sulpice, L.; Daniel, L.; Chirani, S.A. Modeling of functional fatigue of SMA-based actuators under thermomechanical loading and Joule heating, *International Journal of Fatigue*, Volume 179, **2024**, 108055, doi: 10.1016/j.ijfatigue.2023.108055.
156. VOSviewer software official web page. <https://www.vosviewer.c>

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.