Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals & Proceedings of DAAAM International 2011

CONTROLLING THE STROKE OF SHAPE MEMORY ACTUATOR WIRES

GHEORGHITA, V[iorel]; GUEMPEL, P[aul]; CERON LOPEZ, A[rturo] E[duardo] & STRITTMATTER, J[oachim]

Abstract: *In this paper we give a short introduction to elements with shape memory effect and discuss their potential in automotive applications. In the second part of the paper we present a prototype of a NiTinol wire controller. The presented mechanism is suitable for applications in various fields, for example automotive industry and medical industry. It is necessary to control the stroke of shape memory alloy actuator in order to set the desired proprieties. The NiTi-Controller is a device designed to control the contraction-elongation of shape memory alloy wires when they are loading a weight. Normally the lengths of the wires used are between 75 and 125 cm, and the maximum contraction-elongation is 5% of its original length.*

Key words: *shape memory alloy, microcontroller, fuzzy controller, automotive systems, actuators*

1. INTRODUCTION

This application can be used in direction of automotive safety systems and comfort systems. New cars have currently three types of safety systems: passive, pre-crash and active. In these safety systems shape memory alloys can act as actuators which even can respond in milliseconds (Strittmatter, Gümpel & Zhigang, 2009). When these materials are heated the martensitic structure is changed into austenitic structure. During this phase transformation a shape memory actuator is able to contract, to bend or to rotate. The use of shape memory alloys as actuator material has some main advantages: they are smaller and easy to drive with the electrical source and therefore their usage often reduces the complexity of the systems. Thereby weight and size of these systems also can be reduced. . Furthermore the shape memory actuators fulfil their function noiseless which is an important advantage concerning applications in the comfort area.

2. SHAPE MEMORY ALLOY ACTUATORS

2.1 Short introduction about SMA

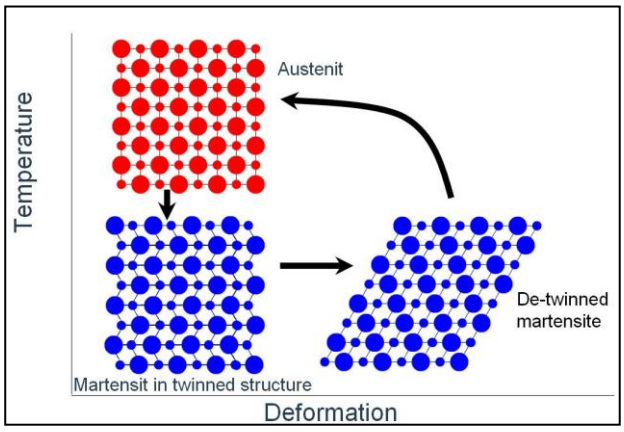

Fig. 1. Martensitic transformation and shape memory effect

Shape memory alloys (SMA, smart metal, memory metal, memory alloy, muscle wire, smart alloy) are alloys that "remeber" their original, cold-forged shape by returning to the pre-deformed shape by heating (Gümpel & Mitautoren, 2004).

2.2 Proprieties of the SMA

Nowadays in engineering the following alloys are used: Nickel-Titanium (NiTi), Copper-Zinc-Aluminum (CuZnAl), Copper-Aluminium-Nikel (CuAlNi) and iron based alloys (Gümpel & Mitautoren, 2004; http://www.thefullwiki.org/ Shape_memory_alloy, Accessed on).

Shape memory alloys show different shape memory effects: one way, two way and pseudo elasticity.

The one way shape memory effect takes place when a shape memory alloy is in its cold state (below A_s): the metal can be bent or stretched and will hold those shapes until heated above the transition temperature. Deformation in this case can be used reversibly until 8%.

During the two way shape memory effect the material remembers two different shapes: one at low temperature, and one at the high-temperature. (Strittmatter, Gümpel & Zhigang, 2009).

3. STROKE CONTROLLER

The NiTi-Controller is a device designed to control the contraction-elongation (stroke) of shape memory alloy wires when a force is applied to the wire (like a loading weight) while it undergoes a temperature change.

The demonstrator has seven main parts: minus clam (1), distance sensor (2), shape memory alloy wire (3), plus clam (4), displacement sensor (5), energy source (6), controller (7).
This demonstrator has three functions: to find the maximum displacement, to set the displacement of the wire and hold it and to introduce an external signal to change the displacement.

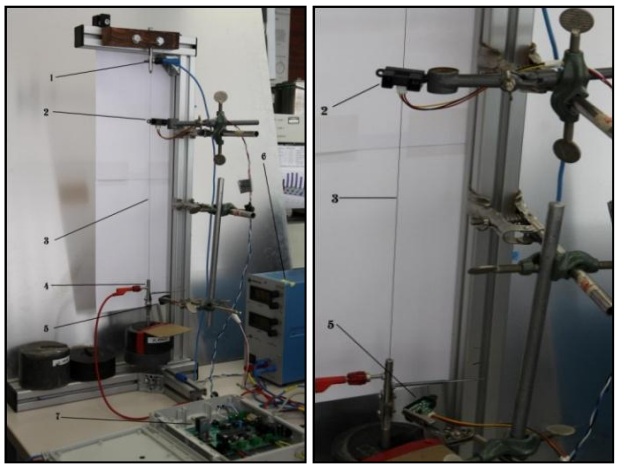

Fig. 2. Demonstrator and sensors

For a given shape memory alloy wire with a certain diameter and length, the maximum displacement can be found with this demonstrator. The wire can contract up to 8% from the length, depending of the tension. The SMA wire can be actuated from external information, like a distance sensor (2). This application is controlled with a NI LabView program.

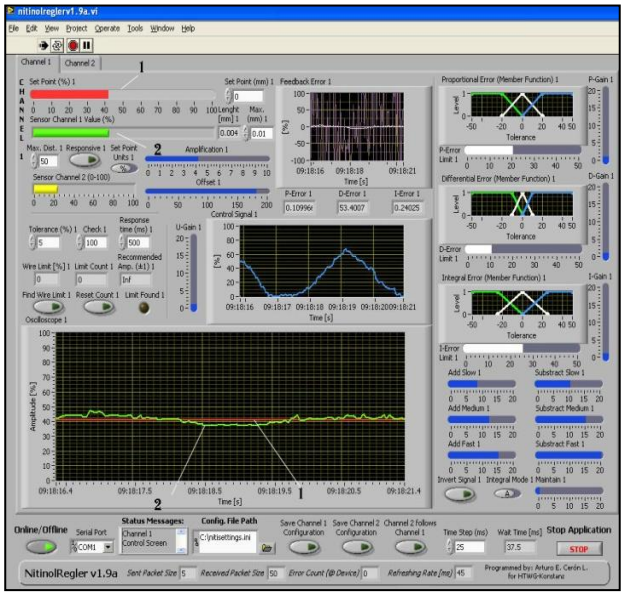

Fig. 3. NI LabView applications

1 – Represents the desired position (could be also a signal from sensor 2)
2 – Sensor 1 reaction (shape memory alloy stroke reaction)

When a desired position is set for the wire (the red line from the Fig.3), the shape memory alloy wire will respond adjusting the stroke with this set value (green line).

For the main processing unit, a dsPIC30F4013 microcontroller was used at 30 MIPS. A Fuzzy PID controller is implemented in the microprocessor's software, with two integration modes, adjustable time step, adjustable set point, adjustable gains and adjustable triangular member functions. This type of control was used mainly because NiTinol wires present hysteresis in their response, and with the help of independent member functions, this approach is suitable for this kind of application (Kwan & Nguyen, 2007), also the control gets friendlier for the user.

For current injection, MOSFET drives were used due to their capability of handling the current load required by the Nitinol wires; pulse width modulation (PWM) was implemented as driving method due to its use feasibility (Ma & Song, 2003; Dunlop & Garcia, 2002). Two Channels with three parallel outputs are available.

Set points can be established manually, or controlled using the channel 2 sensor, if an object is far away, the wire will relax, if it is closer, the wire will contract.

Amplification, Offset, PID Gains and Member Function Settings can be modified by the user, as well as signal inversion and the selection of the integration mode.

4. POSIBLE APPLICATION OF SMA ACTUATORS

The motivation is to do research upon the possibility to use shape memory alloys in automotive safety system. Some conditions for these systems are: to be easy to use (comfort area), to be retractable (pre-crash area), to be faster (crash area). The actuators present on a car can be divided generally into three categories: low power actuators for comfort and bodywork functions, high power vehicle control actuators, and high frequency engine control actuators (Auricchio, 2001). In automotive industry they can replace electrical, thermal, hydraulic, magnetic actuators from different systems, like safety systems, clutch drive, folding and setting mirror, and others by showing additional advantages.

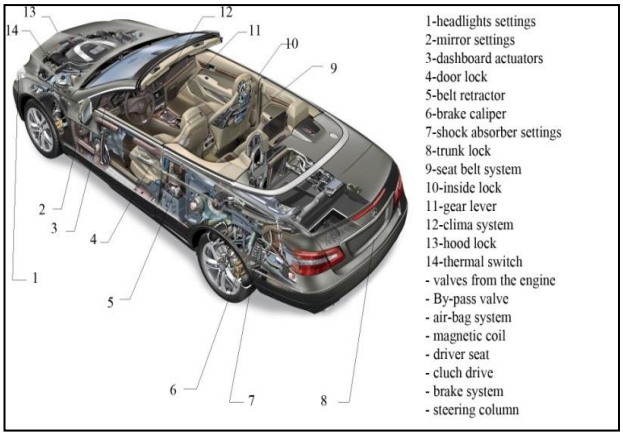

Fig. 4. Possibilities to use SMA in car systems (http://mercedes-benzblog.blogspot.com/2010_03_08_ archive.html)

5. CONCLUSIONS

A new controller was developed to protect the shape memory alloys from overheating when they are activated in order to hold a desired end position over a long period of time. The stroke controller fulfils this task using the minimal electrical energy. Concerning the present research it can be concluded:

- stroke controller will protect the circuit and also the shape memory element,
- stroke controller can hold it the wire at maximum elongation without to damage him, and without to change the proprieties
- stroke controller can change the elongation, when it has information from an external sensor

6. REFERENCES

Auricchio, F.; Faravelli, L.; Magonette, G. & Torra, V. (2001), *Shape Memory Alloys Advances in Modelling and Applications*, International Center for Numerical Methods in Engineering, ISBN 84-89925-82-8, Barcelona

Dunlop, R. & Garcia, A. (2002). A NiTinol Wire Actuated Stewart Platform, *Australasian Conference on Robotics and Automation*, pp. 122-123, November 2002, Auckland

Gümpel, P. und 5 Mitautoren (2004), *Formgedächtnislegierungen*, Expert Verlag, ISBN 3-8169-2293-7, Renningen

Kwan, K. & Nguyen, B.K. (2007). Position Control of Shape Memory Alloy Actuators Using Self Tuning Fuzzy PID Controller, *International Journal of Control, Automation, and Systems*, Vol. 4, No. 6, pp. 756-762

Ma, N. & Song, G. (2003). Control of shape memory alloy actuator using pulse width modulation, *Institute of Physics Publishing*, Vol. 12, pp. 712-719

Strittmatter, J.; Gümpel, P. & Zhigang, H. (2009). Long-time stability of shape memory actuators for pedestrian safety system, *Journal of Achievements in Materials and Manufacturing Engineering* 34/1, pp. 23-30

(***) http://www.thefullwiki.org/Shape_memory_alloy, Accessed on: 2011-07-25

(***)http://mercedes-benzblog.blogspot.com/2010_03_08_ archive.html, Accessed on: 2011-07-25