# SHAPE MEMORY ALLOYS COMPOSITE BISTABLES ACTUATORS

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**Abstract:** *Due to high energy consumption, shape memory alloys composites (SMC) actuators are often rejected. It is necessary for the actuators to require energy only to change their state. In order to maintain a balanced position it is not required energy. With a small amount of energy, these SMC actuators in an equilibrium state can toggle to another position in a split second. Energy is only needed for the switching process.*

*Developing a methodology for designing bistable structure is a first step towards the design of microstructures that act as bistable materials. These materials have interesting applications as actuators and sensors, but have disadvantages associated with, for example, the response in time, the amount of energy required to switch, and the ease of introducing energy into the system. This type of mechanisms are based on energy storage properties to get the bistable behavior.*

**Keywords:** *actuators, shape memory alloys composites*

## 1. General considerations

Developing a methodology for designing bistable structure is a first step to design microstructures that act as bistable materials. These materials have interesting applications as actuators and sensors, but have disadvantages associated with, for example, the response in time, the amount of energy required to switch, and the ease of introducing energy into the system. This type of mechanisms are based on energy storage properties to get the bistable behavior [1].

In fig. 1. is presented a qualitative analysis of energy and voltage variation to a bistable typical case. Curve has three critical points, two points of minimum C and G and a point of maximum, E.

When the system is unloaded or loaded with small loads, the structure will operate around one of the two minimum. Transition from one configuration to another requires adding energy to skip maximum and get close to other minimum. These points can be used to measure performance, which can lead to optimization of bistable periodic structures.

A typical load-displacement curve is shown in fig. 2.

The function used here is built around characteristic points of load-displacement curve.

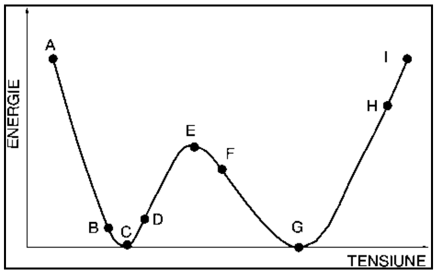


**Figure.1.** *Energy and tension in the structure of a typical bistable [1]*

D and F correspond to the load if only reaches the critical value. Under external loading, B and H are points where attachment structure is expected. Points C and G correspond to the two stable configurations. A measure of distance between these two points is used to construct the function [2].

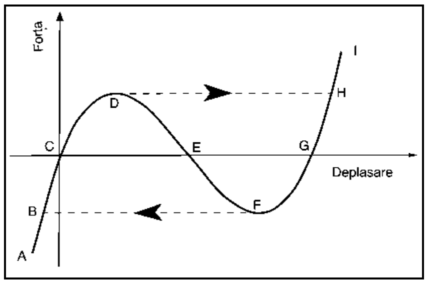


**Figure.2.** *Typical load-displacement diagram for a bistable structure [2]*

## 2. Experiments

At a poor heating, actuator switch from divergent meniscus shape in the convergent meniscus. It is sufficient that the heating cause martensitic transformation start for the SMA, for the meniscus to switch position.

Primary heat treatment of the composite (850oC, 20min, cooling in ice water), is made following that the shape if the insertion (and the composite) to be convergent disk. By this treatment, the matrix of shape memory alloy (SMA) is homogenized, and the spring steel insertion is quenched.

This shape can be obtained and maintained in the heat treatment furnace with the aid of a device made from two complementary spherical parts where the composite is pressed (fig.3.).

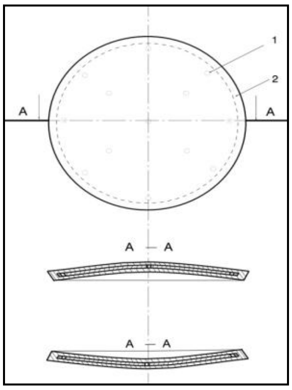


**Figure 3.** *Actuator from SMC bistable disk type: 1 – spring steel perforated disk; 2 – SMA matrix*

Actuator dimensions and also of the device, are given by the work that will be produced. The composite hot form is imposed by primary heat treatment (850oC, 20min, cooling in ice water), but also by the secondary heat treatment (470oC, 10 min), where the composite becomes convergent disk by pressing (fig. 3.). The hot shape is imposed to the SMA matrix and the insertion will be normalized. With this shape the composite is maintained into the oven during the secondary heat treatment.

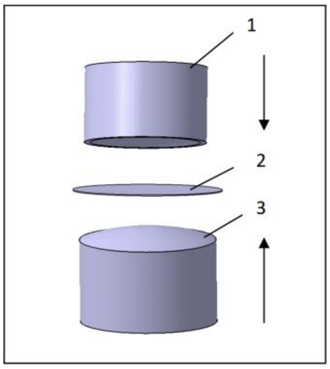


**Figure 3.** *Device for imposing the hot form: 1 – superior part with convergent spherical cap; 2 – plan disc composite; 3 – bottom piece with divergent spherical cap*

The cold shape for the composite is given by the insertion shape and the matrix and is made by cold pressing (fig.4.).

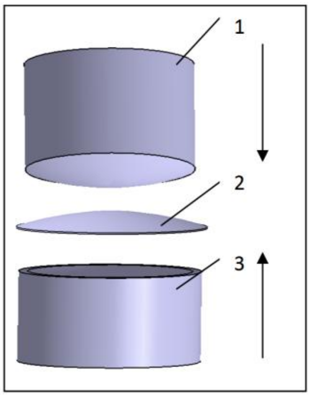


**Figure 4.** *Device for imposing the cold form: 1 – superior part with divergent spherical cap; 2 – composite divergent disk; 3 – bottom piece with convergent spherical cap*

The imprinting processes for the hot shape and the cold shape at the disk actuator are schematically presented in fig. 5.

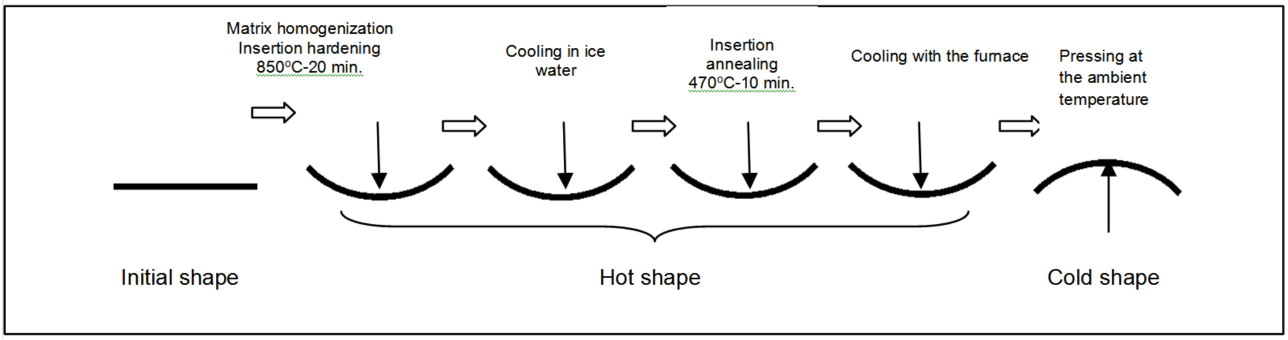


**Figure 5.** *Imprint diagram for the hot form and cold form for the composite actuator disc, bistable type.*

Finite element analysis allows us to observe (fig.6.) the stress level for a virtual bistable actuator, with a disk shape, made from a SMC matrix (SMA type CuZn14Al16 and spring steel insertion). The actuator diameter is 40 mm, actuator thickness is 0,5 mm, insertion thickness is 0,1 mm, loaded with a uniform distributed compression of 1N. The maximum level of stress at 80% of this load is presented near to the fixing area, then follows a stress gradient toward the middle of the actuator, area where minimal stress occurs (2,42x$10^3$ N/$m^2$). This gradient of elastic deformations, lead to swinging of the convergent meniscus into the divergent meniscus.

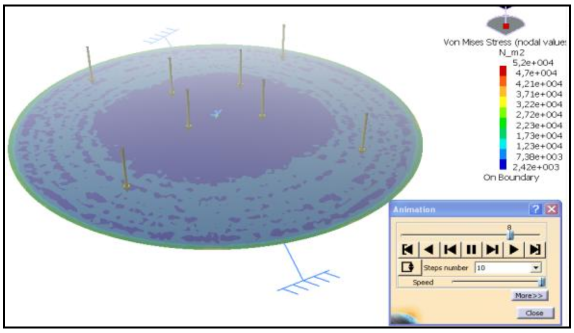


**Figure 6.** *The stress level for a virtual bistable actuator with a disk shape, made from a SMC matrix, loaded with a uniform distributed compression of 1N*

In fig. 7 is observed the displacements fields for a virtual bistable actuator, with a disk shape made from a SMC matrix, loaded with a uniform distributed compression of 1N. The minimum level for displacements is presented in the fixing area, 0mm, then follows different displacements on concentric areas. The maximum displacement area is represented in red (4,32x$10^{-5}$mm), toward the middle of the actuator. This elastic deformations gradient makes the actuator to swing from divergent meniscus into the convergent meniscus.

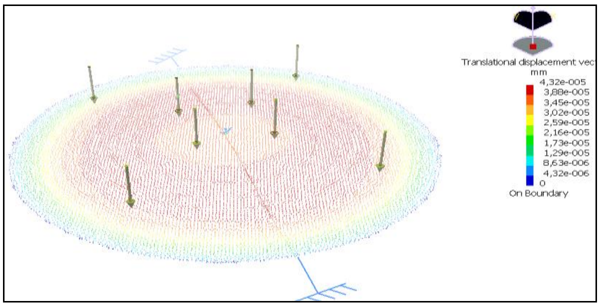


**Figure 7.** *The displacement fields for a virtual bistable actuator with a disk shape, made from a SMC matrix, loaded with a uniform distributed compression of 1N*

This SMC matrix can be used as a thermal protection element, by connecting or disconnecting electrical or mechanical elements. Tipping pulse intensity can be controlled mechanically by using a compression coil spring.

## 2. Conclusions

With the values obtained by the finite element analysis can be drawn graphics like stress-energy (fig. 1) and force-displacement (fig. 2) for different dimension types of the bistable actuators. These curves can be used to measure the actuators performance, in order to optimize bistable periodic structures.

## 4 References

[1] Zhang, R.X., Ni, Q.Q., Natsuki, T., Iwamoto, M., *Mechanical properties of composites filled with SMA particles and short fibers.* *Compos Struct*, 2007;79: 90–6.

[2] Payandeh, Y., Meraghni, F., Patoor, E., Eberhardt, A. *Effect of martensitic transformation on the debonding propagation in Ni–Ti shape memory wire composite*, Mater Sci Eng A 2009;518:35–40.