SHAPE MEMORY ALLOYS

Definition

It is usually agreed that the shape memory material Nickel – Titanium (known as SMA, Shape Memory Alloy) has been discovered and developed in the 50-60' by the "Naval Ordnance Laboratory" in the USA. The commonly used name is ***NITINOL*** (**Ni Ti** for Nickel & Titanium and **NOL** for Naval Ordnance Laboratory).

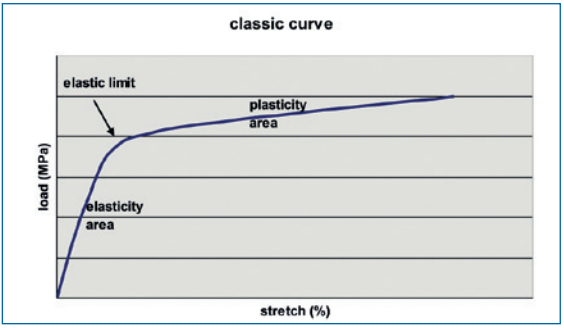
There are several types of shape memory alloys, which include other elements, such as Copper and Iron. Nevertheless, the only one, which exhibits biocompatibility properties, and thus can be used for medical implants and instruments, is a equi-atomic alloy of Nickel & Titanium with some trace of Oxygen (approx. 500 ppm – part per million).

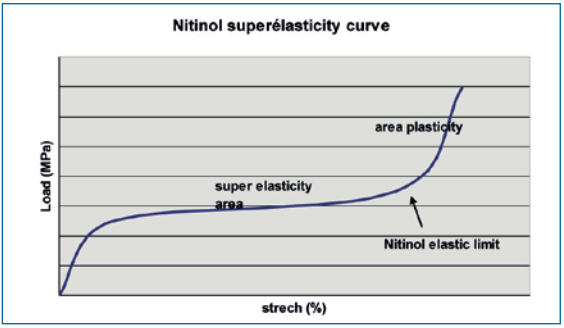
The Oxygen combines with the Titanium to form a passivated layer of TiO2 on the surface of the component. This thin layer with high resistance properties to the environmental conditions plays an important "shielding effect", and avoid Nickel atoms to diffuse, knowing that Nickel has toxic effects to the body.

Intrinsic properties (physical, mechanical, biologic tribologic....)

Nitinol is a biocompatible alloy with very special properties. For example, and depending of thermo-mechanical treatments, it can behave as:

- Superelastic : When bended, it always comes back to its original shape, as soon as the stress is released.
- Shape Memory: The wire is quite soft, and it can be deformed at room temperature, but as soon as it is warmed, it takes its original shape. Approx. 10°C is enough from the beginning and the end of the shape recovery. This temperature can be precisely set between 10°C et 50°C (This is the ideal case for medical applications).





- Reversible elastic deformation with a minimum of 5% .
- Constant stress elasticity : As soon as the plateau limit is achieved, the Nitinol deforms till the end of the plateau, without any increase of the stress.

Shape Memory effect of the NITINOL

The obvious application of the shape memory effect is the so called "Bone Staple" for the osteosynthesis operations in the orthopeadic surgery.

Biocompatibility

The Nickel Titanium alloy complies with the international standard ASTM F2063-05, which describes the biocompatibility properties of the NITINOL. Case studies related to this biocompatibility can be found on Internet (google → biocompatibility + oulu + nitinol).

Where does the NITINOL come from – Manufacturing process – Production process

AMF is a fully integrated manufacturer of NITINOL semi-finished products and components.

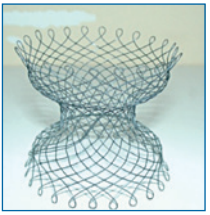
Following processes are applied:

- Rolling.
- Wire drawing.
- Wire shaping.
- EDM cutting.
- Tribological and electro-polishing.
- Mechanical and fatigue testing.

The NITINOL pre-material is supplied by smelters, expert in the manufacture of Titanium alloys. Usually, processors use pre-material, starting from rods or wires in the range of 5 up to 25mm. It is then rolled or drawn in different cross sections, typically 4 x 4mm down to 1 x 1mm, or rectangular cross sections which can be much smaller (0.35 x 0.55mm). Round wires range is 4mm down to 0.10mm.

Bigger pre-material allows to roll strips of approx. 30mm wide in different thickness. These strips can then be wire EDM cutted.

Typical applications



99% of the SMA applications are dedicated to the Medical Devices:

- Osteothythesis bone staples (for the foot and hand surgery).
- Dental reamers (for the treatment of root canals).
- Flexible reamers shafting in orthopaedics.
- Guide wires for the cardiology.
- stents (based on braided wires or laser cutted tubes).

1% is dedicated to the Aerospace technology:

- Safety devices.
- Actuators for solar panels deployment.

Other applications:

- Bra garments.
- Instruments for magic actors (forks which change of shape with the body temperature).
- Jewelry.

Avantages for the dedicated applications

- Flexibility of the superelastic wires (up to 5% elastic deformation).

- The shape memory effect allows to develop and manufacture micro-actuators without any components in motion, 100% safe and without any limit in term of life time.

A shape memory component can stay "on hold" for decades and become active as soon as the defined parameters are achieved.

Limitations

The limits of SMA devices are defined by the performances required after a certain number of working cycles of deformation.

- Superelasticity: 9% deformation can be obtained with a thin wire (small grain size of the alloy) and for a limited number of cycles.
- The shape memory material and applications have relatively poor fatigue résistance in superelastic conditions. 10'000 cycles is a reasonable limit. For extended requirements, further developments have to be implemented. In any case, as better the surface of the component is, as better the fatigue behavior will be.
- Shape memory effects have similar limits than superelasticity.

Typical test procedures to ensure a good quality

Based on the complex behavior of the material, it is a must to perform a full range of tests in the "live" conditions, in term of required deformation and number of cycles.

Extensive fatigue tests are required for applications which have more than 100 cycles. The reason is that parameters like surface quality and grain size of the material might affect the quality of the finished product.

Mechanical and fatigue tests are performed on orthopaedic implants (typically 10 millions cycles test at 430 daN for hip joints).

Partner

AMF was founded in 1988. AMF is part of the "Groupe Lépine", french leader in the development, manufacture and distribution of orthopaedic prothesis and intruments. AMF is staffed with engineering background in materials for the medical community and shape memory alloys.

AMF is a worldwide manufacturer and supplier of SMAs.

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