Design of an SMA actuated laparoscopic forceps

DSD

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Introduction

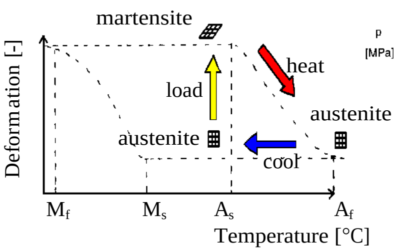
Laparoscopy is a surgical technique involving small incisions in the abdomen through which surgical procedures can be performed. The DSD group is investigating the use of Shape Memory Alloy (SMA) actuators in a laparoscopic forceps. The SMA is used to close the forceps while the opening is done by a spring. Because the spring reacts too slowly, it has to be replaced by a second SMA, used as an antagonist.

Goal

Design an experimental set-up in which a laparoscopic forceps can be opened and closed by two SMA actuators. In this setup, the forces of both SMA's and the angle of the forceps have to be measured.

SMA working principle

An SMA is an alloy (Nitinol) that can transform from the martensitic phase to the austenitic phase (MA) by heating the alloy [1]. This transformation causes a strain decrease of ca.6%. If the austenite reaches a temperature below A_s the austenite can be transformed to martensite (AM) again by loading the wire with a relatively small force (see figure 1+2).



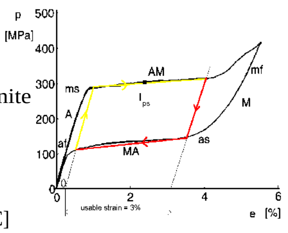


figure 1: the cycle of the shape memory curve effect; s=start, f=finish

figure 2: stress- strain of a SMA at T>A_f

The deformation of an SMA wire is decribed by the Gree-Lagrange strain. The usable strain is ca. 3% (see figure 2) .

$$e = \frac{1}{2}\left(\left(\frac{l}{l_0}\right)^2 - 1\right) \approx 3\%$$

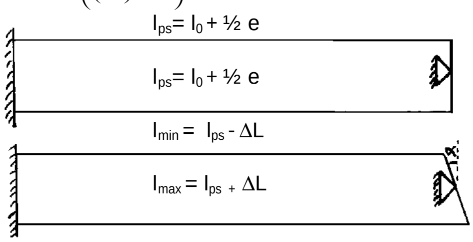


figure 3: rotating of the joint by heating wire 1

When two wires are placed parallel and applied to a joint, they can be used as antagonists. They both have to be prestrained(l_{ps}) at ½ of the usable strain(e). The wires are applied to the forceps such that after prestraining the opening angle is 9°. To close or open the forceps, the joint will rotate over + or - 9°.When wire 1 is heated and decreases in length(-ΔL), this wire loads wire 2 which will increase(+ΔL) in length. As a result, the joint will rotate over an angle α = 9° (see figure 3).

Experimental set-up

The wires will be heated by a current of 1 A and are able to generate forces up to 30N.When the forceps are closed, the torque that the forceps generates can be described by (see figure 4):

$$-F_1 \cdot a_1 + F_2 \cdot a_2 - T_f = -F_3 \cdot b$$

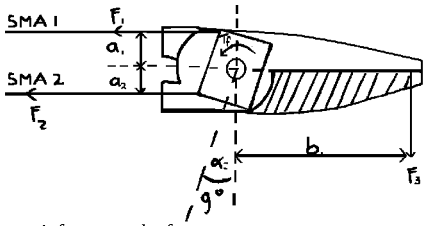


figure 4: forces on the forceps

The picture below shows us the experimental setup with measurement equipment (figure 5).

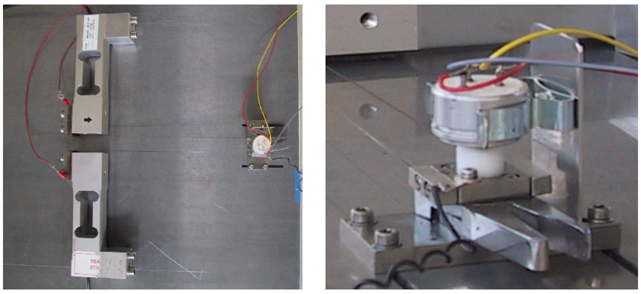


figure 5: (left)experimental setup with a potentiometer to measure the angle of the forceps and two loadcells to measure the force of each SMA. (right) close-up from the forceps

Future research

- Design of a control strategy for position- and force feedback for the SMA's such that this information can be provided to the surgeon.
- Research on the feasibility of SMA's in the human body.

References

[1] Marc van der Wijst, *Shape control of structures and materials with shape memory alloys*, Eindhoven 1998

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