

Control of shape memory alloy actuators

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Control of Shape Memory Alloy Actuators

M. van der Wijst, M. Moens, P. Schreurs, F. Veldpaus and H. Meijer



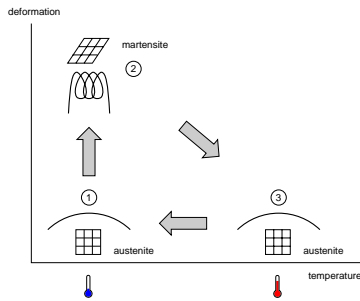
Eindhoven University of Technology,
Faculty of Mechanical Engineering,
Section Materials Technology,
P.O. Box 513, NL 5600 MB Eindhoven



Introduction

Shape Memory Alloys (SMAs) are metal alloys that exhibit the *Shape Memory Effect*:

an SMA deformed at a low temperature (① → ②), recovers its original shape upon heating (② → ③).



This process is due to a change in crystal structure from austenite to martensite and vice versa. It is repeatable for millions of times.

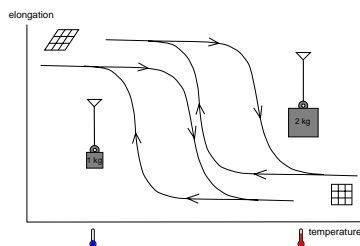
Objective

Application of SMA wires as actuators for mechanical systems. This implies the development of a control strategy, using a model of:

- the 1-D constitutive behaviour of SMA wires
- the heating and cooling behaviour of SMA wires (energy balance)
- the mechanics of the system

Constitutive behaviour

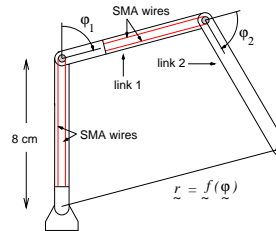
Characteristics:



- heating ⇒ wire shortens
- cooling ⇒ wire elongates
- hysteresis: shrinkage starts at higher temperature than elongation
- hysteresis loop shifts to higher temperatures when a larger force is applied

Experimental setup

Two-link robotarm driven by two pairs of SMA wires (Nickel-Titanium, cross-section: 0.1 mm x 0.6 mm)

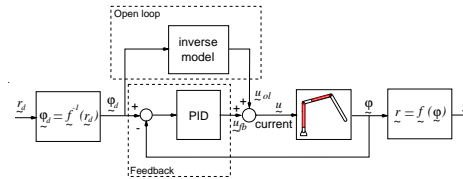


Problem definition

Let arm tip $\underline{r} = [r_x \ r_y]^T$ follow a desired trajectory \underline{r}_d . Since \underline{r} cannot be measured directly, the control task is defined as: let the link angles $\underline{\varphi} = [\varphi_1 \ \varphi_2]^T$ follow a desired trajectory $\underline{\varphi}_d = [\varphi_{1d} \ \varphi_{2d}]^T = \underline{f}^{-1}(\underline{r}_d)$.

Control strategy

Adjust the temperature of the SMA wires by adapting the electric current \underline{u} through the wires.



Two control laws were investigated:

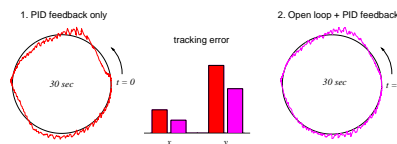
1. $\underline{u} = \underline{u}_{fb}$
2. $\underline{u} = \underline{u}_{fb} + \underline{u}_{ol}$

with:

- \underline{u}_{fb} = PID feedback controller

$$= P(\underline{\varphi} - \underline{\varphi}_d) + I \int_0^t (\underline{\varphi} - \underline{\varphi}_d) dt + D(\dot{\underline{\varphi}} - \dot{\underline{\varphi}}_d)$$
- \underline{u}_{ol} = open loop current based on a (inverse) model of the entire system

Experimental results



Conclusions

- Shape Memory Alloys can be applied successfully as actuators in mechanical systems
- Tracking performance can be improved with a model-based control law