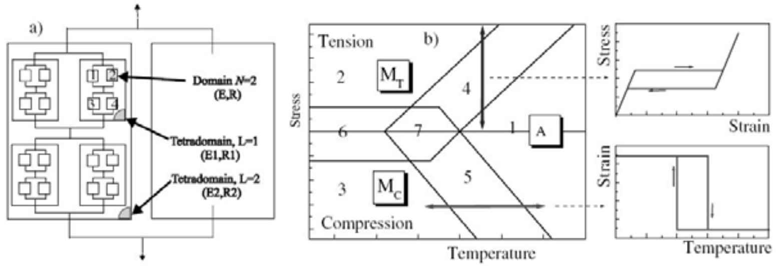
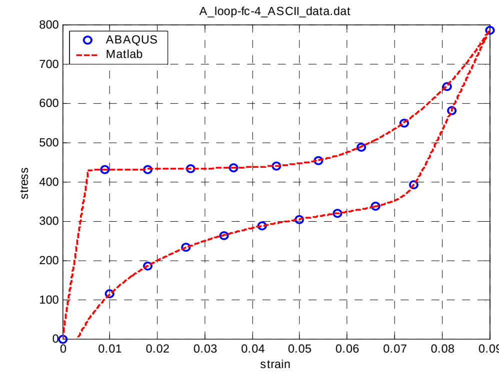


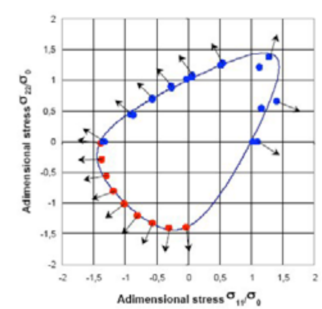


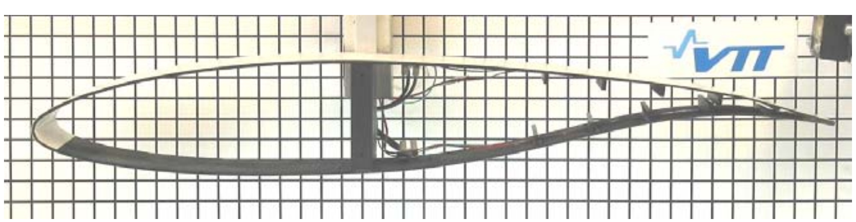
MAFESMA

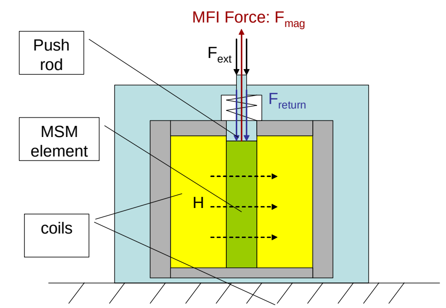
(Material Algorithms Finite Elements Shape Memory Actuators)

Tools for modeling, design and control of smart structural systems based on shape memory alloys (SMA):

Material algorithms,
Finite Element methods, Experiments







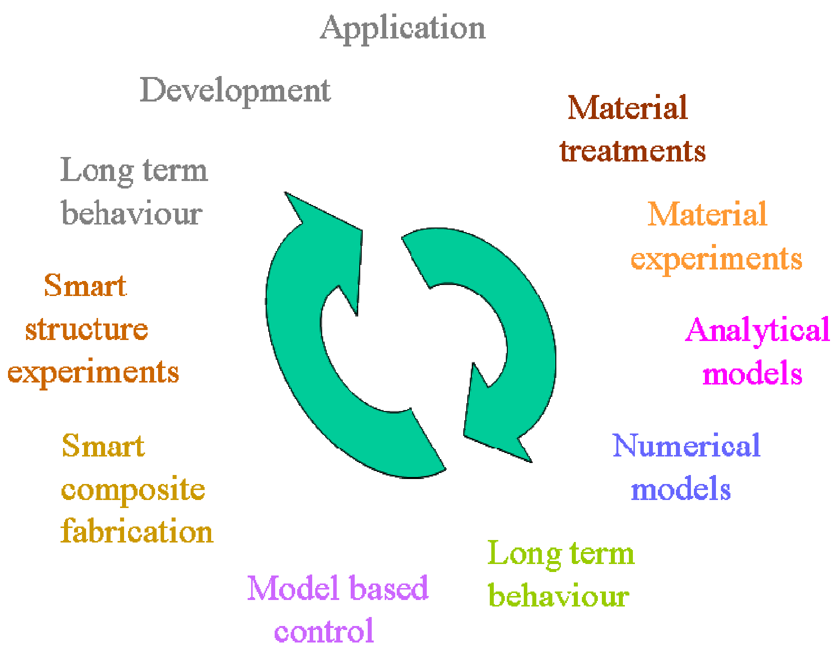
MAFESMA

Collaboration of research groups from four European countries, including some of the top research groups of ordinary SMAs and magnetic shape memory (MSM) alloys

AIM

Bridging the gap between extending **material knowledge** and the **design of active machines and structures**

- Tools for modeling the functional behaviour of SMA/MSM-devices
- Controlling the long term behaviour of SMA/MSM actuators
- Development and control of SMA actuated smart structures, especially smart Fiber Reinforced Polymer composite structures



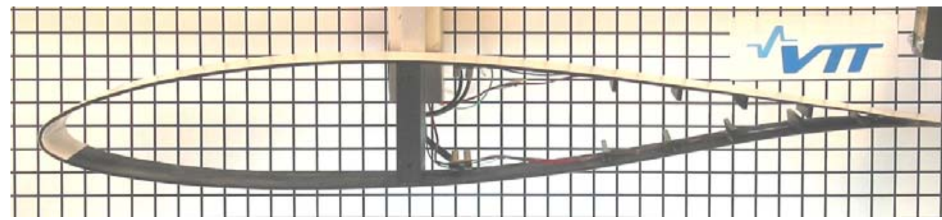
Background

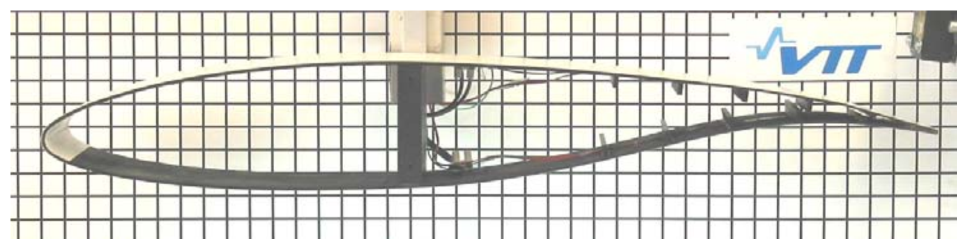
Embedded structural intelligence

Sensing,
decision making,
active reaction,
communication

↓

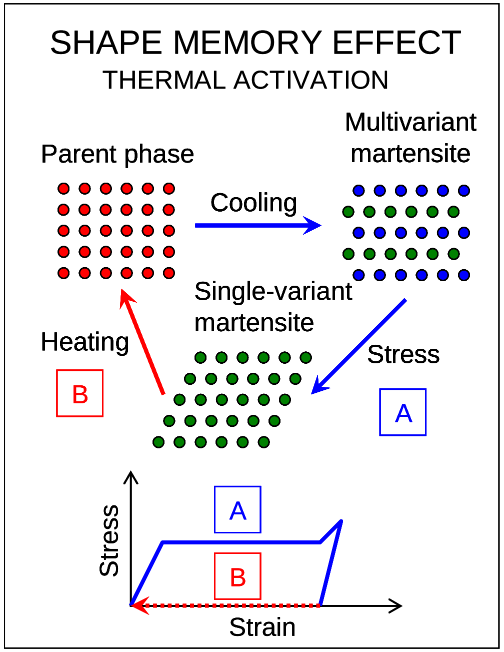
Optimum performance,
new product concepts,
minimized lifecycle costs,
adaptation to all
operational conditions

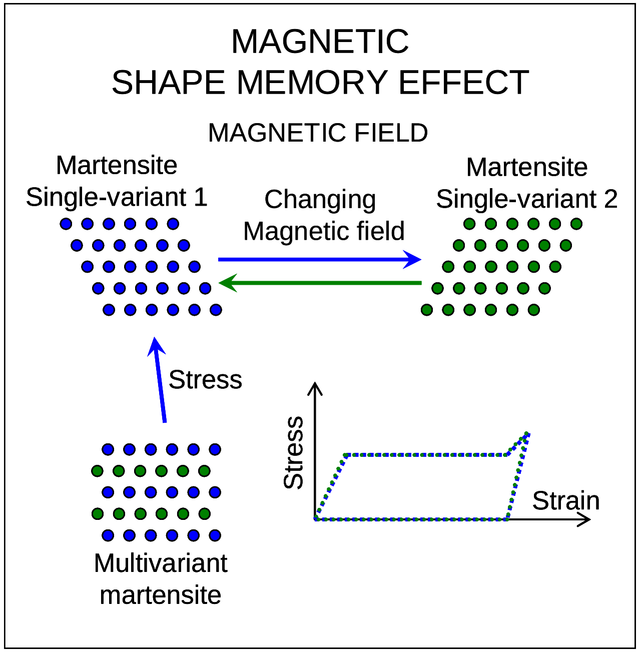


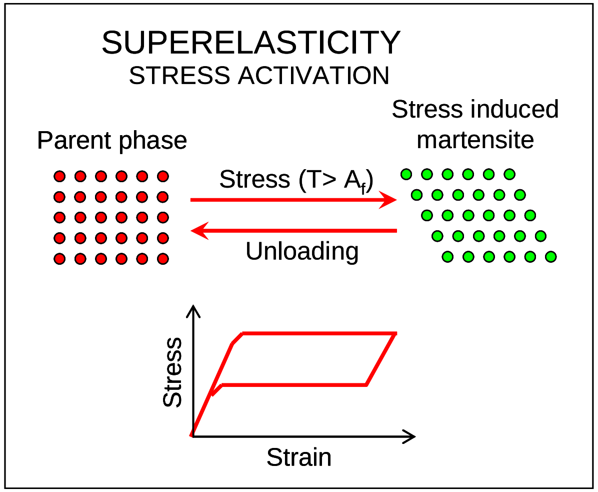


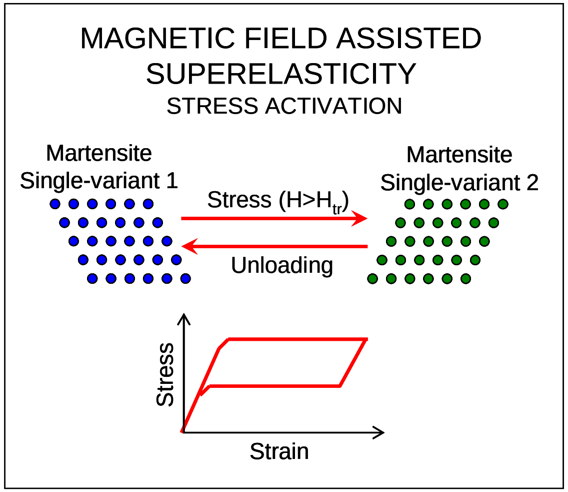
SHAPE MEMORY ALLOYS

- Metallic alloys that react to changes of temperature or magnetic field by changing their shape - even against considerable force
- Often used as passive or on/off devices, but can also be used as actively controlled actuators or sensors
- MAFESMA project focuses on SMAs as actuators in active devices, especially for shape control and semiactive vibration control





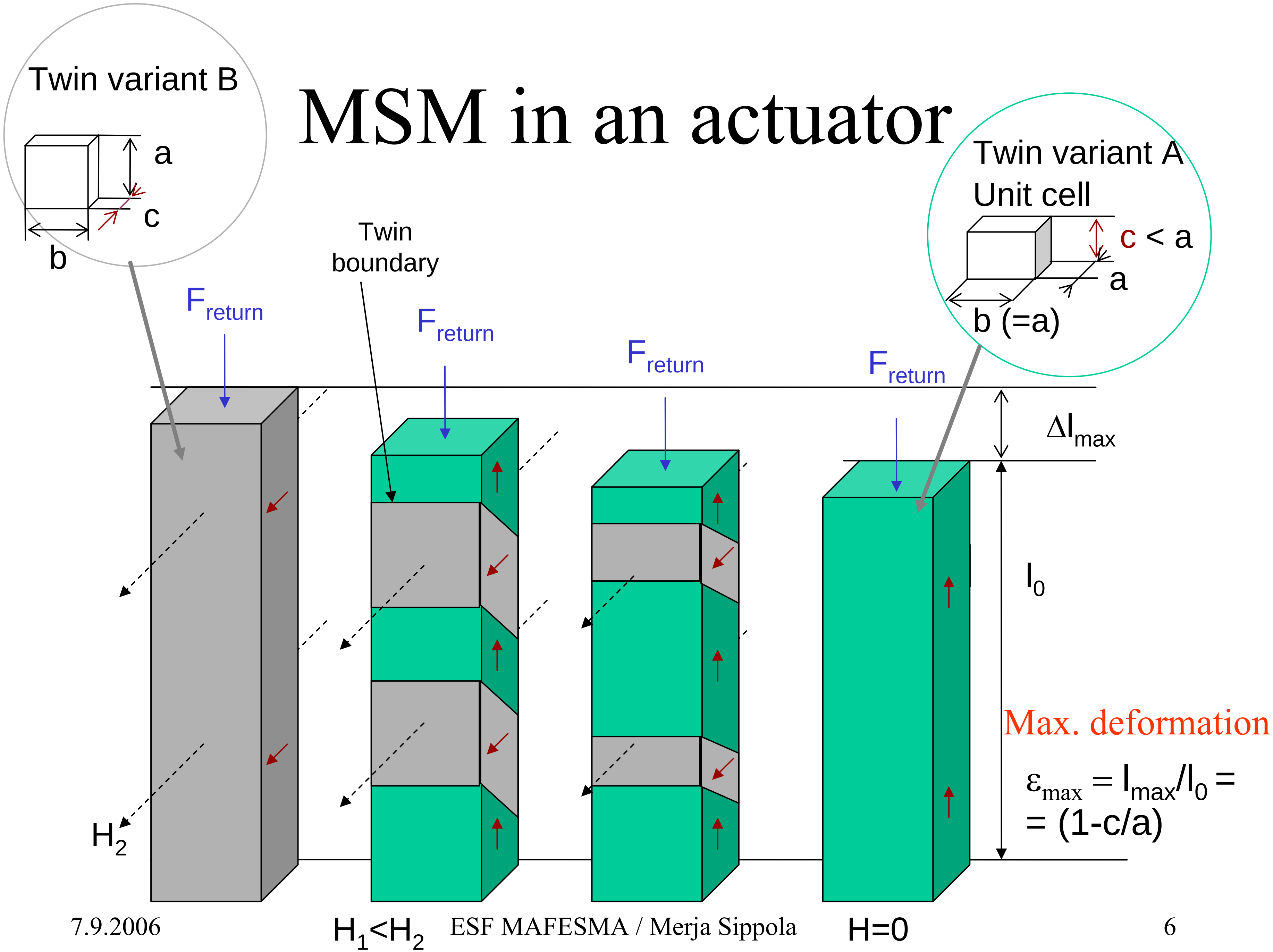




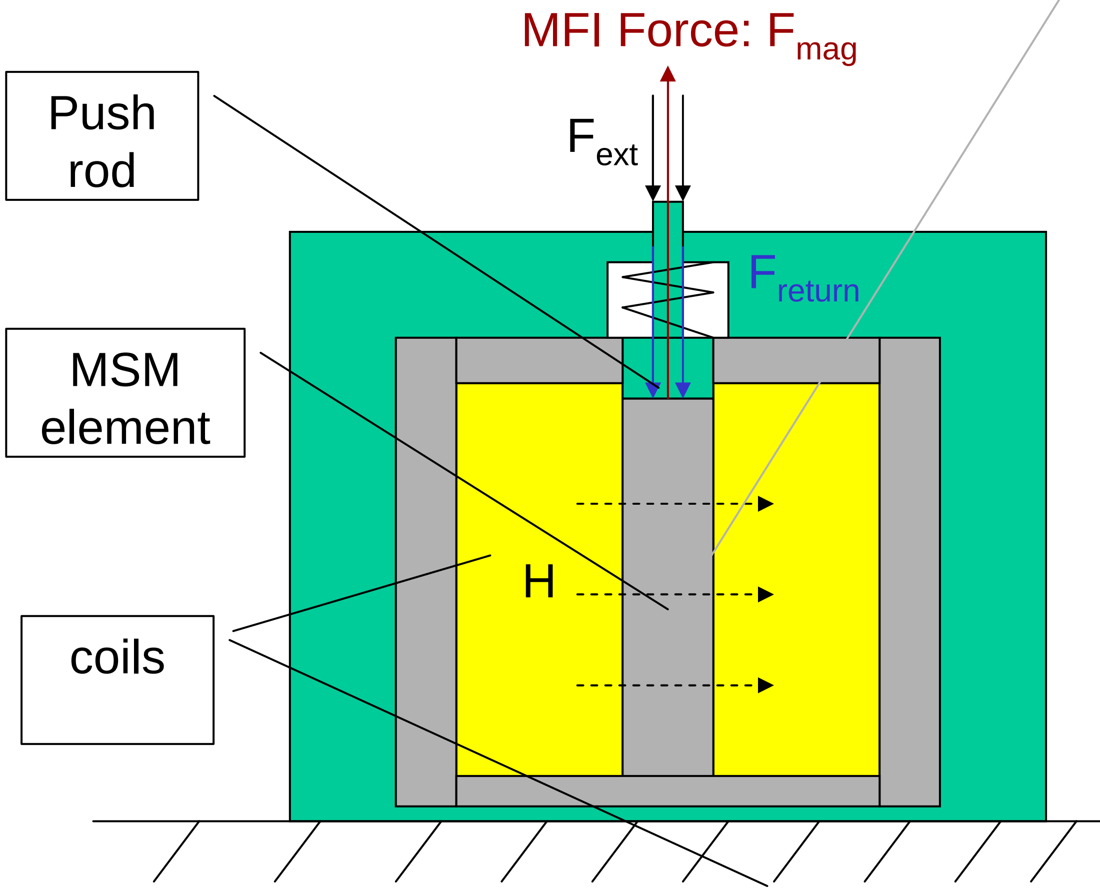
Background - continued

Ordinary Shape Memory Alloys (SMA)	**Magnetic Shape Memory alloys (MSM)**
Actuation by heating and cooling	Actuation by external magnetic field
Resistive heating needs wiring in the actuator	No wiring needed in the actuation element
most used NiTi, NiTiCu, CuZnAl, CuAlNi	most used Ni-Mn-Ga, also Fe-Pt, Fe-Pd, Co-Ni-Ga
shape memory effect (deformation by detwinning of the martensite, heating to austenite structure for the recovery) or stress induced martensitic phase transformation of the austenitic structure and its recovery (superelasticity)	rearrangement of the twin variants in the martensitic structure in alternating magnetic field; also springlike behaviour in the martensitic structure under constant magnetic field; in some alloys stress induced martensitic phase transformation of the austenitic structure by the magnetic field
actuator usually in tension	actuator usually in compression
NiTi max deformation 8 % practical range < 5 %	Ni-Mn-Ga max deformation 6-10 % practical range < 4 %
max superelastic recoverable strain 15 %	
max stress 800 MPa practical range < 200-300 MPa	max stress < 3 MPa practical range about 1-2 MPa, depending on twinning stress
rather slow (max 5 Hz) (R-phase transformation in thin coatings 100Hz)	rather fast (max 380-500 Hz)
biocompatible	not biocompatible

MSM in an actuator



MSM actuator operation (schematic)



"Twinning stress", σ_{tw}, resists the twin boundary motion

Output

$\sigma_{mech} = \sigma_{mag} - \sigma_{tw}$,

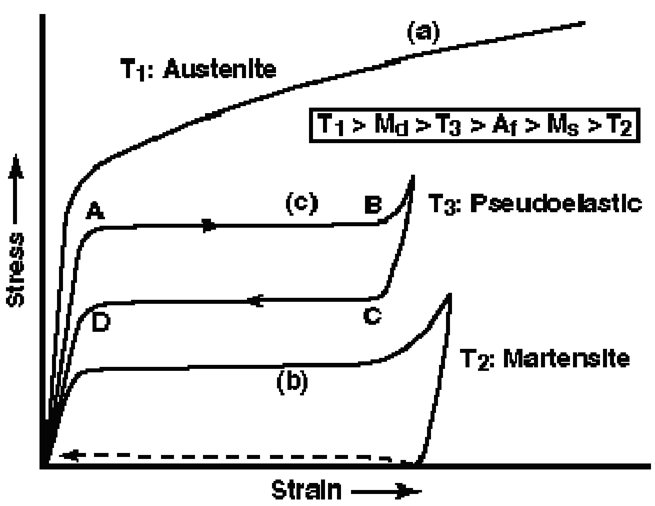
where
σ_{tw} = twinning stress.,
σ_{mag} = magnetic-field-induced (MFI) stress,
σ_{mech} = opposing external stress (working stress) + returning spring stress.

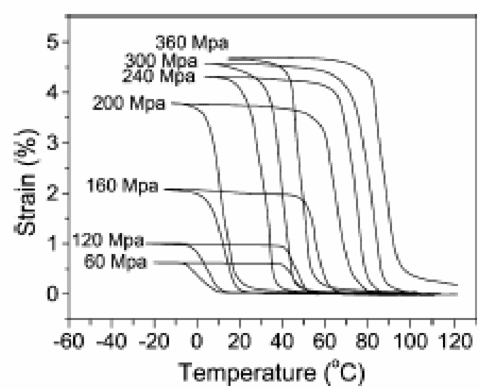
(Likhachev et al. 1999, Heczko et al. 2003)

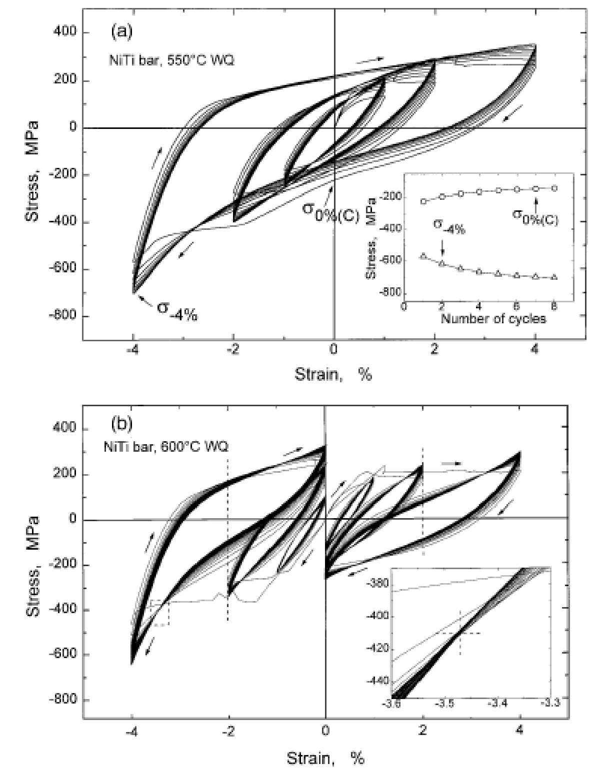
SMAs - continued

About thermally activated (especially NiTi based) SMAs:

- The deformation of stabilized SMA is a hysteretic function of temperature and stress.
- SMAs behave differently in tension and compression.
- Under cyclic loading stabilized SMA follows a repetitive T,σ,ε path.
- In tension-compression cycling of SMA the dislocations created in compression affect the behaviour in tension.







MAFESMA

Research groups from four European countries, including some of the top research groups of ordinary SMAs and magnetic shape memory (MSM) alloys

Each participating group has co-operation links to many other countries through bilateral or European projects.

The participating groups have several other smart materials and structures related projects belonging to a long term research strategy.

Tasks

Developing tools for modeling the actuation cycles (heating and cooling / magnetic) of stabilized SMA (NiTi based wire and MSM) actuators.

Developing model based control systems for SMA / MSM actuators.

Tools for controlling and modeling the long term behaviour of SMA /MSM actuators.

Developing tools for modeling the time dependent behaviour of SMA actuators and SMA actuated FRP composite structures.

Appropriate experiments to control and sustain the models.

Work breakdown

Project Leader:
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KULeuven, Belgium
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Academy of Sciences of the Czech Republic
Professor Christian L'Excellent
Univ. of Franche-Comte, France
Professor Etienne Patoor
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Helsinki Univ. of Technology
Professor Kalervo Nevala
University of Oulu
Dr Pertti Kauranen
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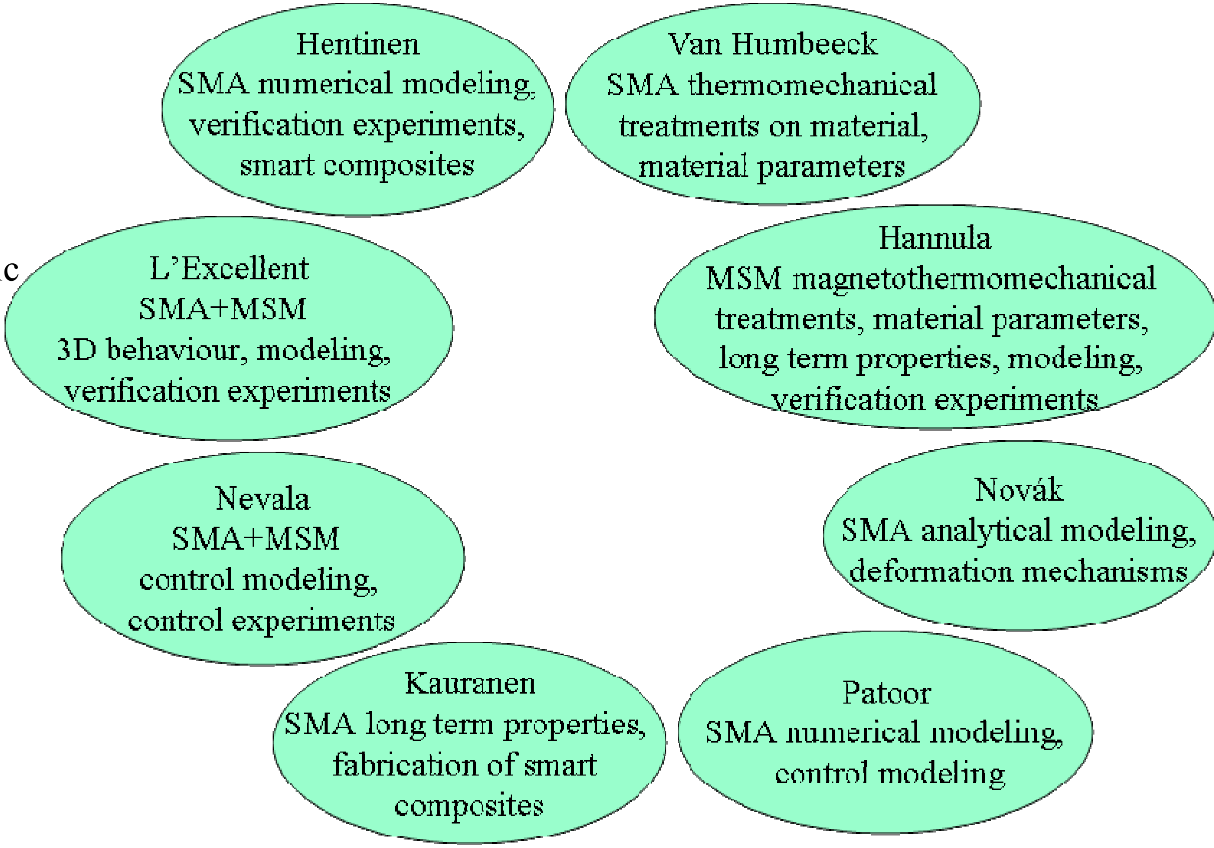
Markku Hentinen
VTT Technical research centre of Finland



CONCLUSIONS

- SMAs have much potential that has not been utilized so far
- Most commercial applications are passive or on/off devices
- SMAs are suitable for actively controlled use, especially in shape control and semiactive vibration control
- This project **tackles the bottlenecks** that hinder the design and development of SMA actuated **active** devices, machines and structures

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