

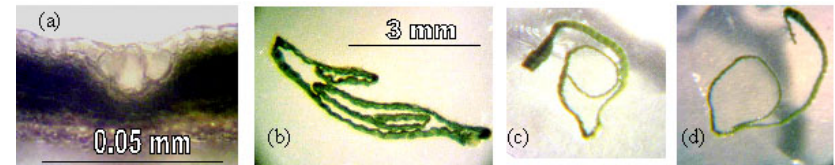
Nabtesco Project

Design of Actuators Based on Ferromagnetic Shape Memory Alloys (FSMA) and its Composites with application to airborne actuators and biomedical devices

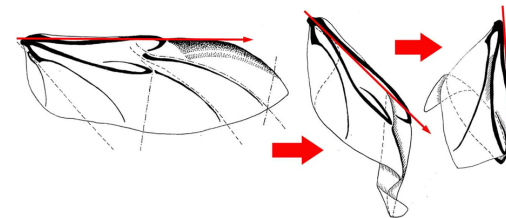
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Goals of Nabtesco Actuators Laboratory at University of Washington, Mechanical Engineering:

1. Design a set of new Airborne Actuators based on new design principles such as bioinspired active materials
2. Design compact and high power airborne actuators based on fast-responsive ferromagnetic shape memory alloy (FSMA) and its composite.
3. Develop a set of new applications of FSMA and FSMA composite actuators, such as biomedical fields with example of nanohelix FePd actuators for cancer diagnosis and treatment
4. Educate ME undergraduate and graduate students, and interns from Nabtesco Corp with the above knowledge.



Folding of European weed leaf exhibits large morphing, (a) zoom up of the upper part of the leaf with expanded motor cells, (b)-(e) sequence of expansion



Horned beetle wing folding sequence, from expanded wing (left) to folding (right) [Nomura, 2010].



Bald eagle flying patterns, (a) cruising, (b) flapping, (c) slow down [Taya, 2006]



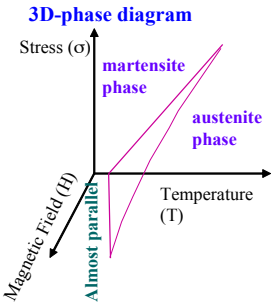
Emergence process of flying dragon (*Anax parthenope Julius*) [Kishimoto and Natori, 2006].

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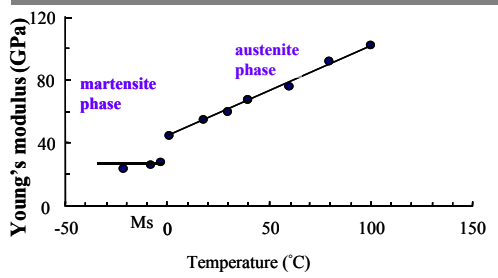


Ferromagnetic Shape Memory Alloy (FSMA): Fast-Response and High Power Active Material

Fundamentals of FSMA and its composite



Hybrid mechanism of FSMA:
 Chain-reaction: Applied magnetic field gradient
 → magnetic force
 → Stress-induced martensite transformation
 → low stiffness of FePd
 → large deformation



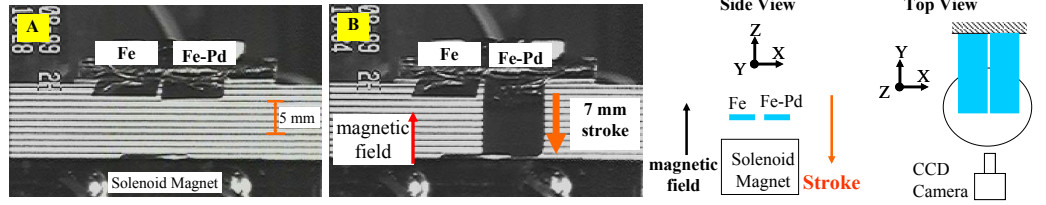
The effect of uniform (constant) magnetic field is very small

$$\sigma_{ij}^t + f_i^m = \rho \dot{v}_i$$

$$f_i^m = \mu_0 M_j^p H_{j,i}$$

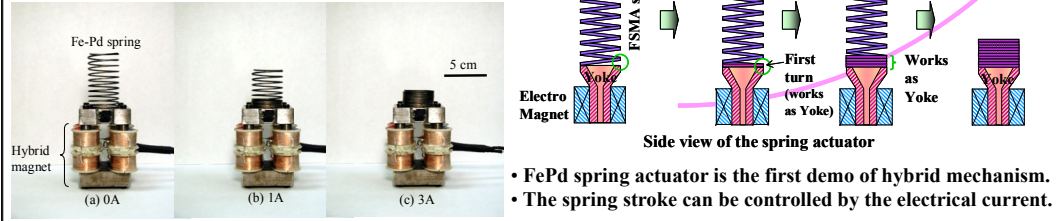
- FSMA is potential as the fast responsive actuator material to be driven by magnetic field.
- The best driving mechanism of FSMA is hybrid mechanism that can produces large strain yet moderate block force caused by the magnetic field gradient.

Demo of hybrid mechanism



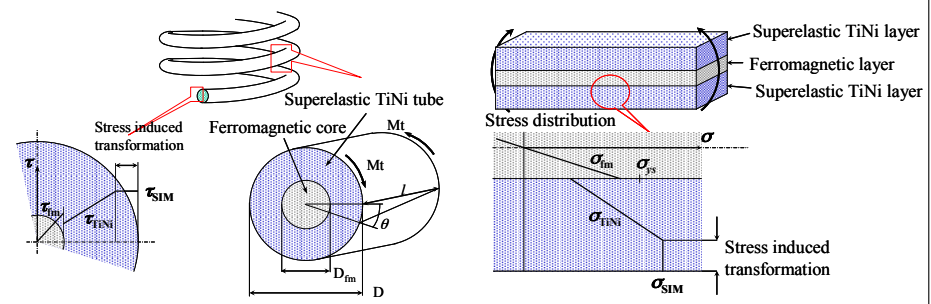
Fe: saturated magnetization (M_s) = 1.8×10^6 Amp/m, $E = 210$ GPa
 Fe-Pd (in austenite phase) : $M_s = 1.6 \times 10^6$ Amp/m, $E_A = 70$ GPa

FePd FSMA spring linear actuator



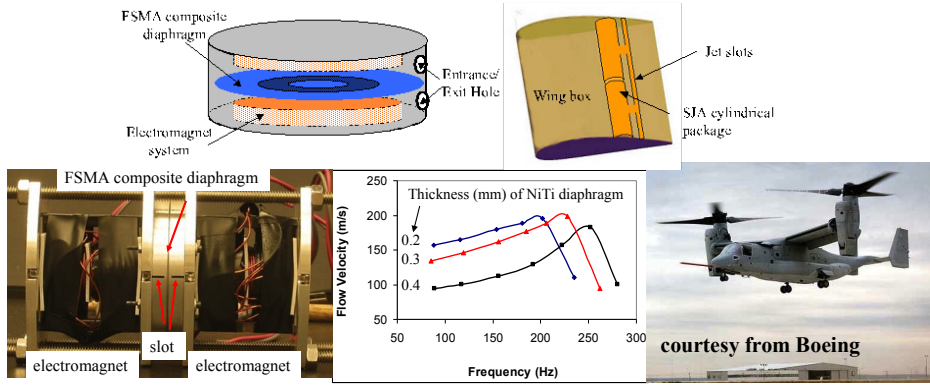
- FePd spring actuator is the first demo of hybrid mechanism.
- The spring stroke can be controlled by the electrical current.

FSMA composite



- FePd is the best actuator material based on the hybrid mechanism, however, Pd is very expensive.
- FSMA composite made of superelastic SMA and ferromagnetic soft iron is the economically alternative material while keep the same performance as FePd FSMA.

FSMA composite based synthetic jet actuator (SJA)



A strong synthetic jet flow is produced by FSMA composite based SJA to aim at improving the aerodynamic performance of aircrafts.

