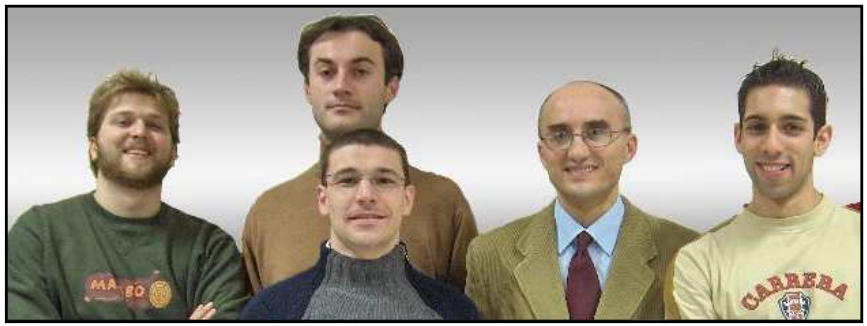
La meccanica degli attuatori a memoria di forma

Eugenio Dragoni
Giovanni Scirè
Andrea Spaggiari
Igor Spinella

Università di Modena e Reggio Emilia

Seminario Università degli Studi di Pavia
31 Gennaio 2014

Gruppo Costruzione di Macchine RE



Materiali leggeri (polimeri, adesivi)

Materiali meccatronici

Materiali meccatronici

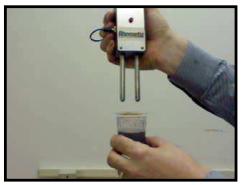
Cambiano reversibilmente caratteristiche reologiche
(forma, rigidezza, viscosità)

se sottoposti a stimolo fisico
(temperatura, campo elettrico/magnetico)

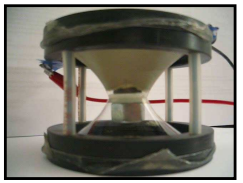
originato da corrente elettrica

Materiali meccatronici

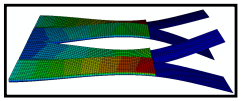
Liquidi magnetoreologici



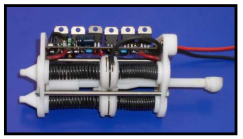
Polimeri elettroattivi



Ceramiche piezoelettriche



Leghe a memoria di forma



Leghe a memoria di forma: attuatori

Principio di funzionamento

Sistemi di riarmo

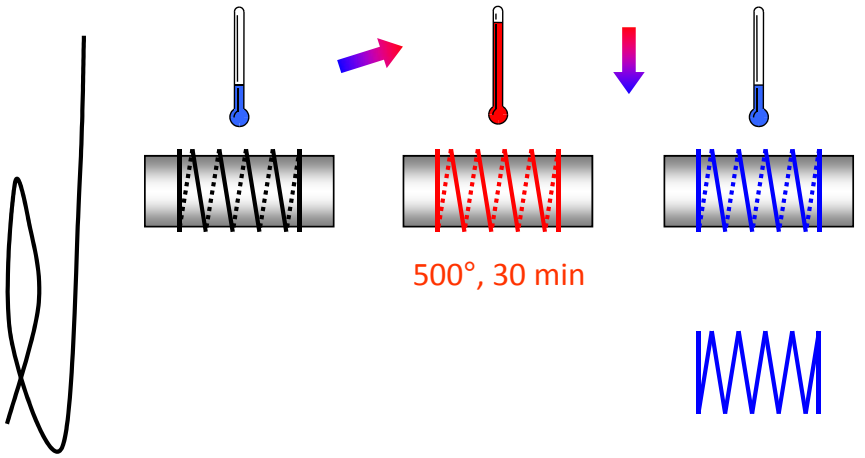
Modelli di comportamento meccanico

Attuatori non convenzionali

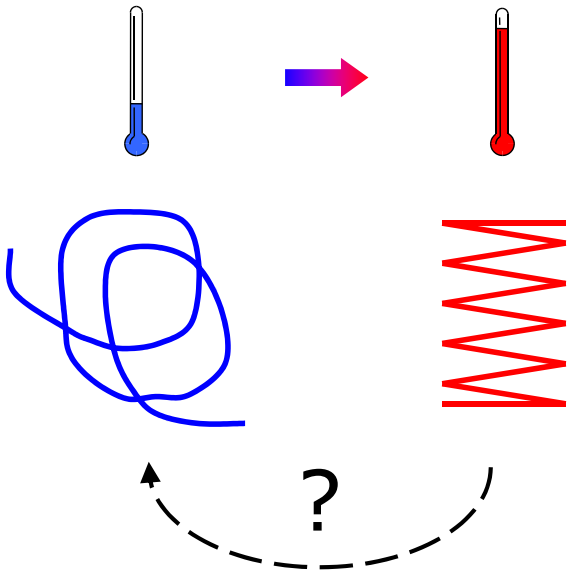
Fatica termomeccanica

Linee di sviluppo

Principio di funzionamento



Principio di funzionamento



Principio di funzionamento

Principio di funzionamento

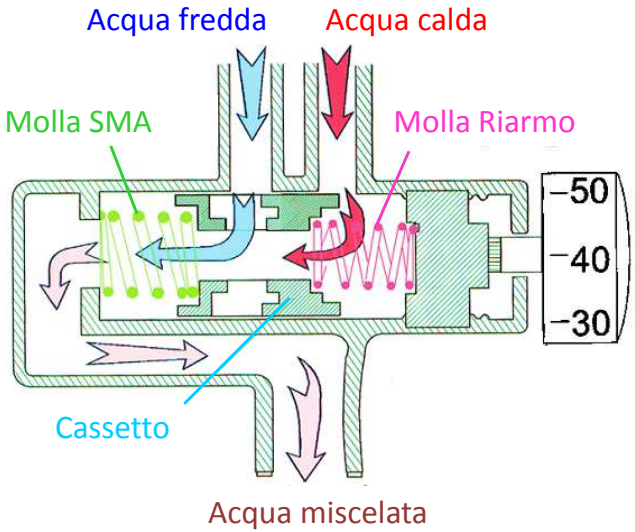
Memorizzazione della forma (una tantum)

Fonte di riscaldamento (corrente elettrica, calore)

Sistema di riarmo (peso, molla, carico esterno…)

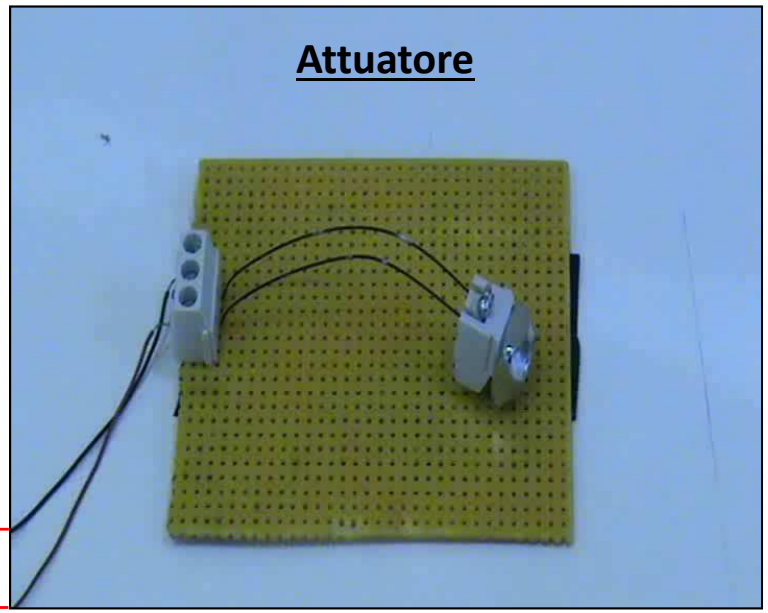
Principio di funzionamento

Sensore-attuatore



Principio di funzionamento

Attuatore



Sistemi di riarmo

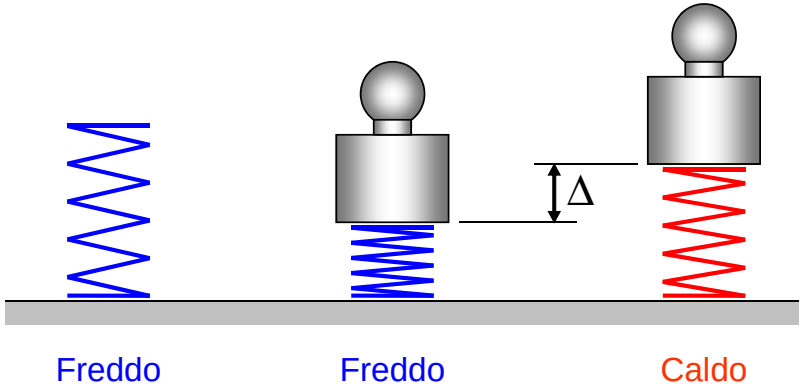
Forza costante (Peso, molla a nastro)

Molla elastica

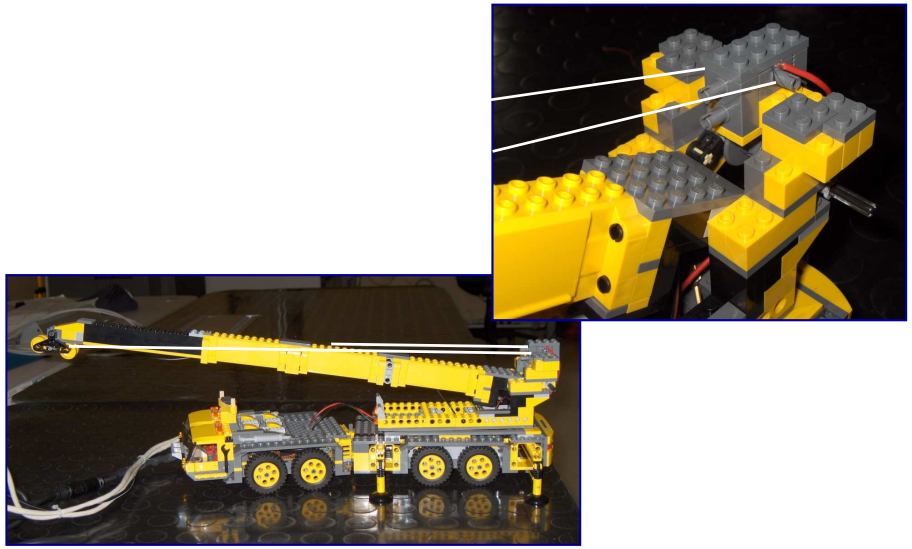
Molla SMA

Compensazione negativa (meccanismi bistabili)

Sistemi di riarmo (forza costante)

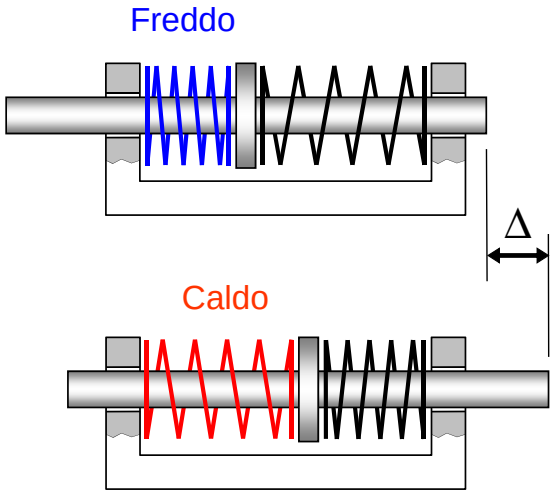


Sistemi di riarmo (forza costante)

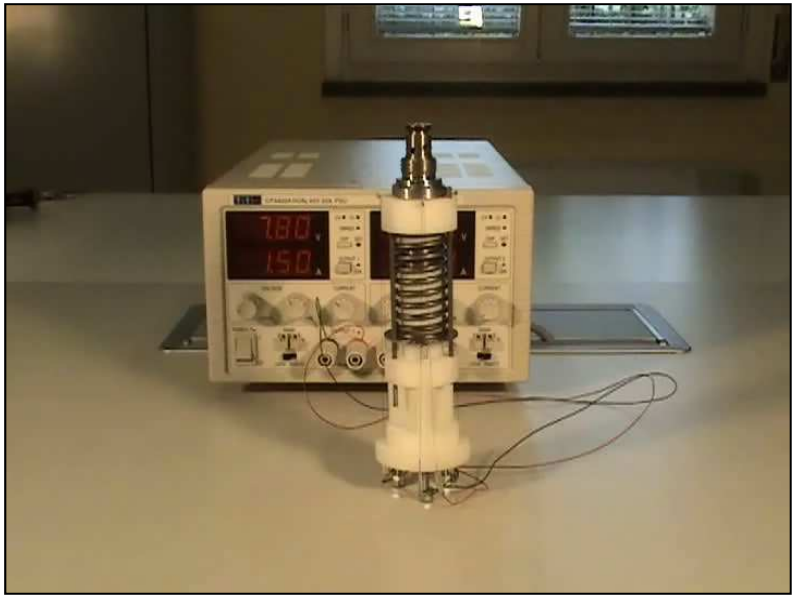


Sistemi di riarmo (forza costante)

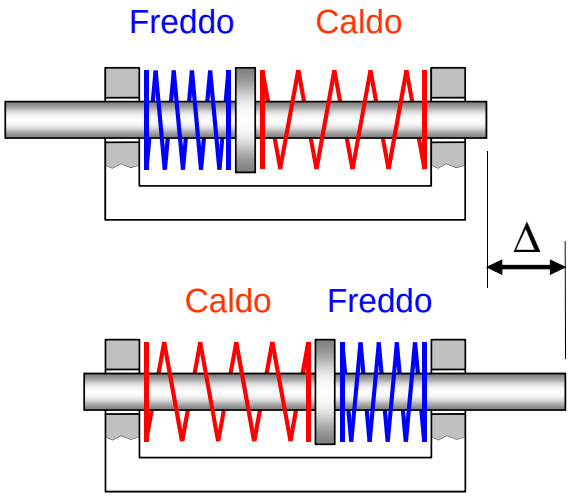
Sistemi di riarmo (molla lineare)



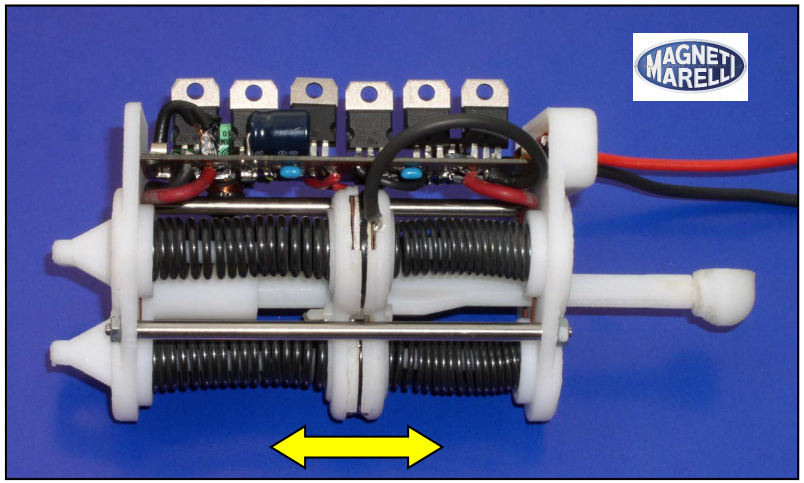
Sistemi di riarmo (molla lineare)



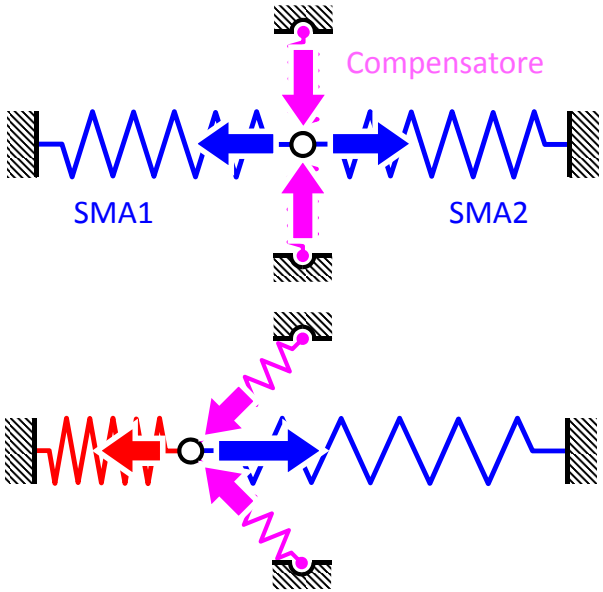
Sistemi di riarmo (molla SMA)



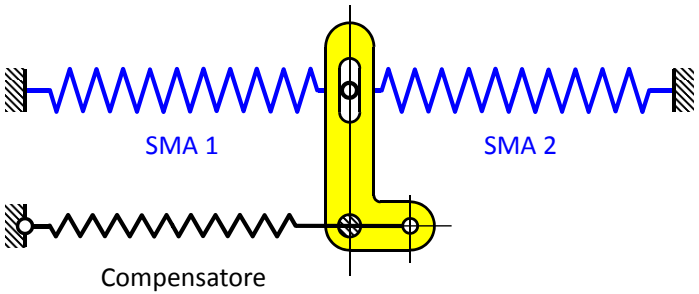
Sistemi di riarmo (molla SMA)



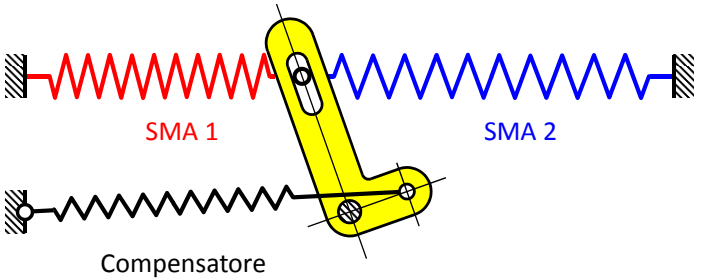
Sistemi di riarmo (compensazione negativa)



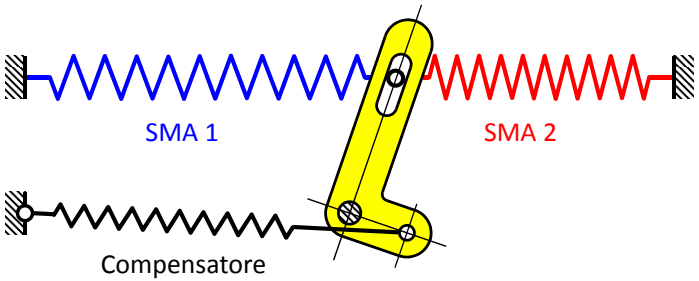
Sistemi di riarmo (compensazione negativa)



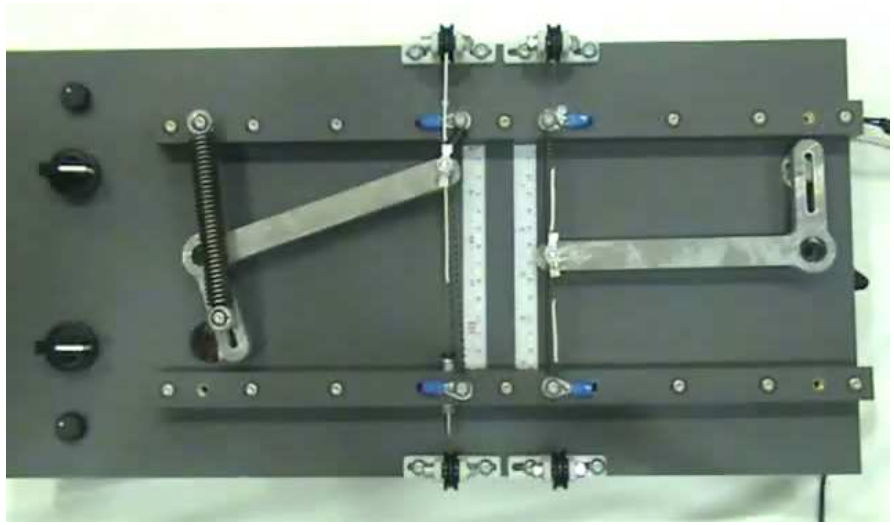
Sistemi di riarmo (compensazione negativa)



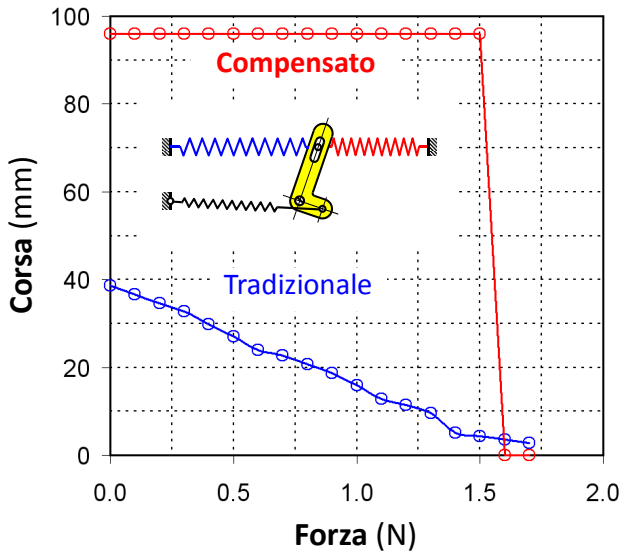
Sistemi di riarmo (compensazione negativa)



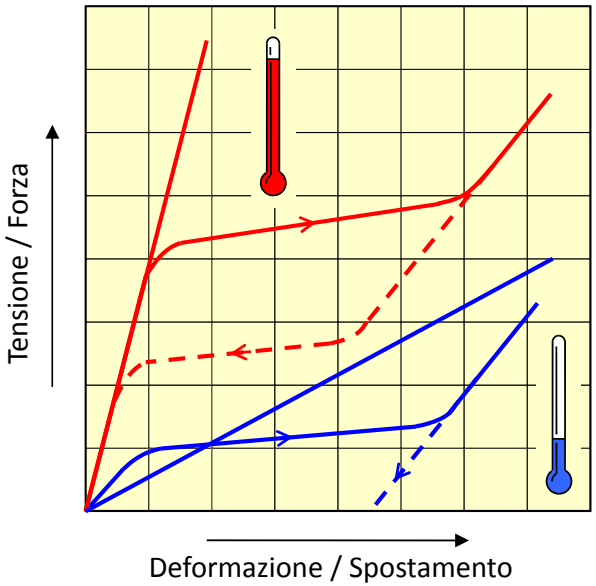
Sistemi di riarmo (compensazione negativa)



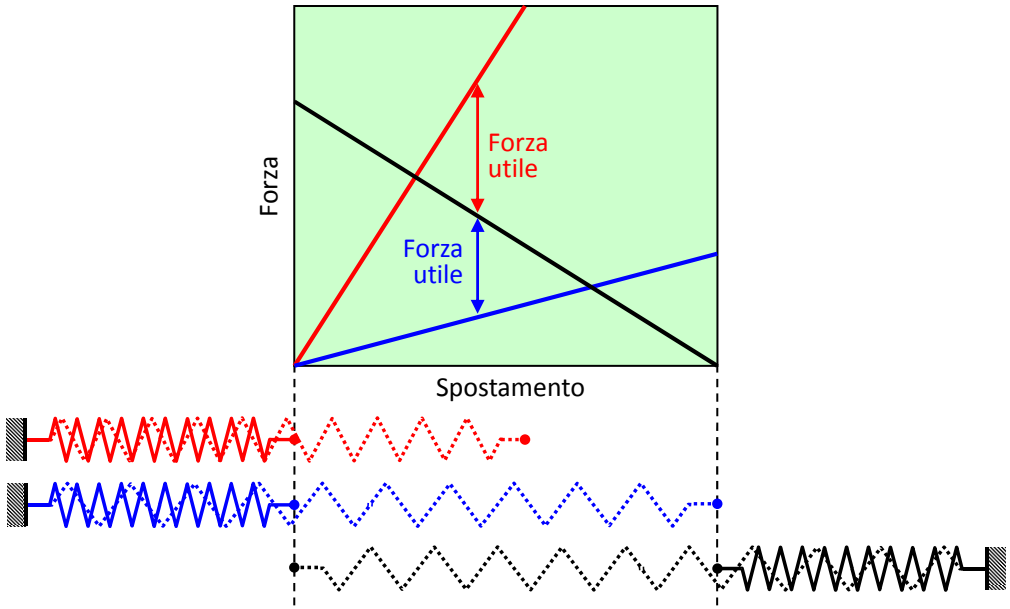
Sistemi di riarmo (compensazione negativa)



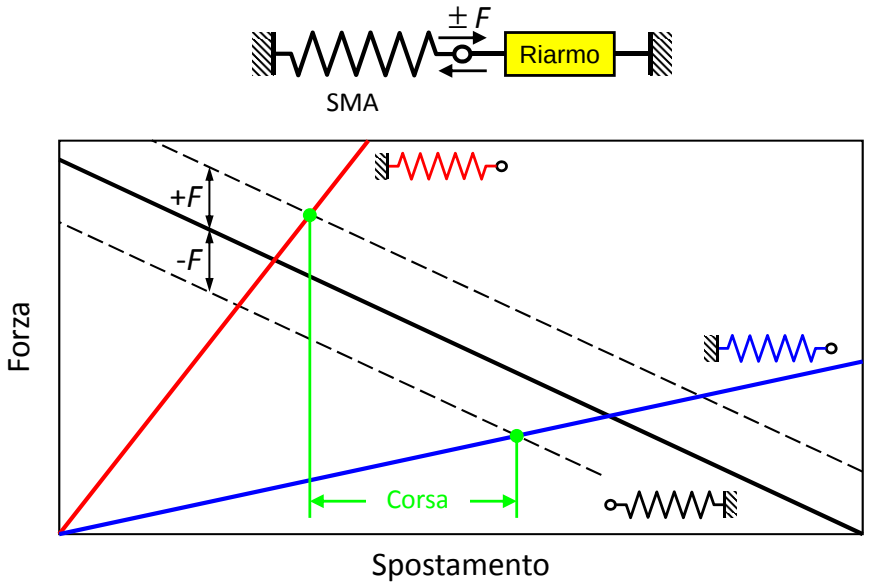
Modelli di comportamento meccanico



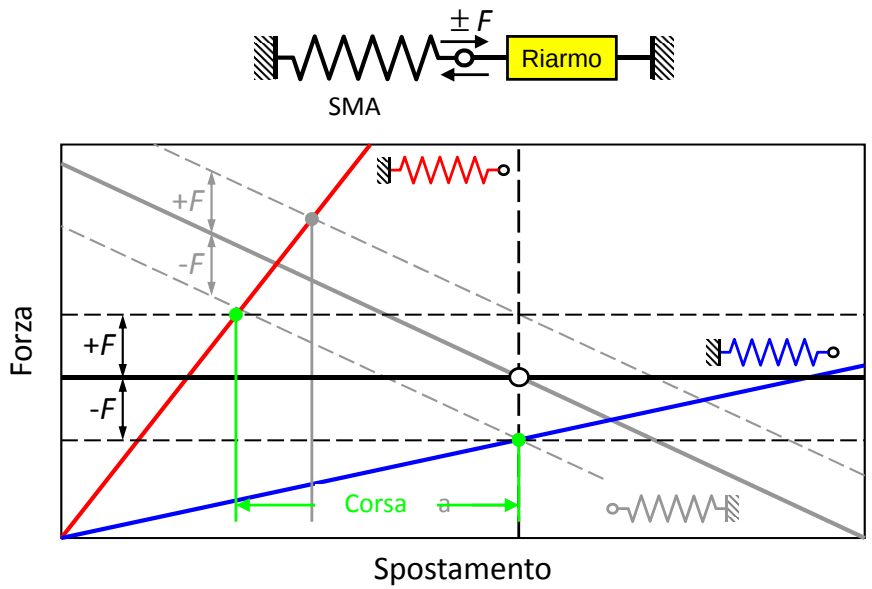
Modelli di comportamento meccanico



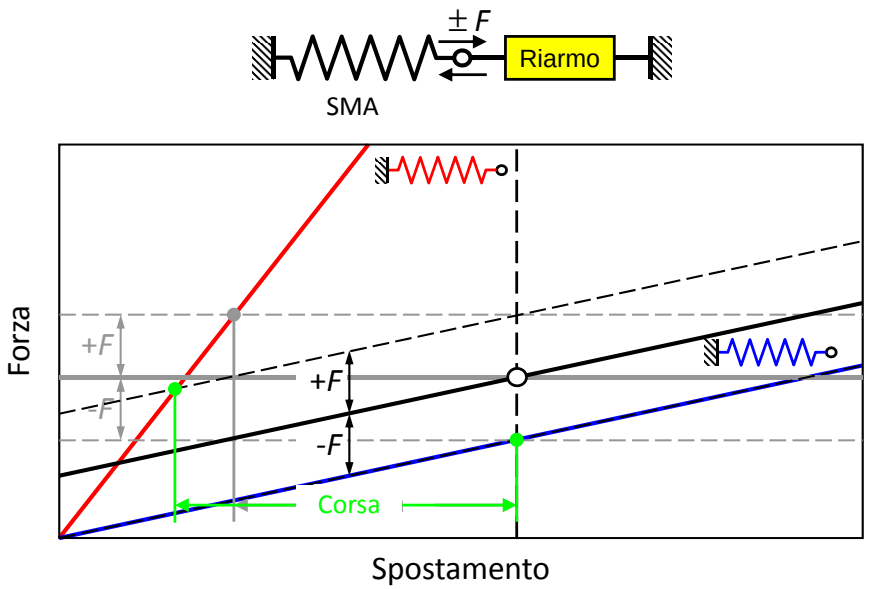
Modelli di comportamento meccanico



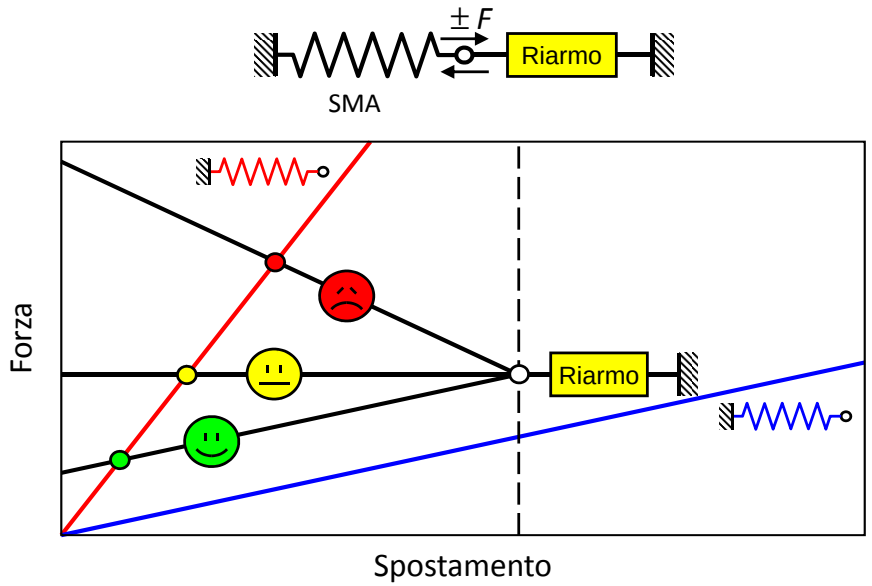
Modelli di comportamento meccanico



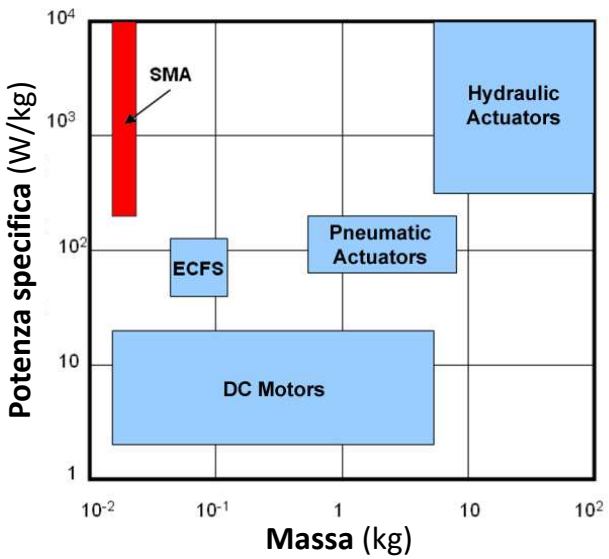
Modelli di comportamento meccanico



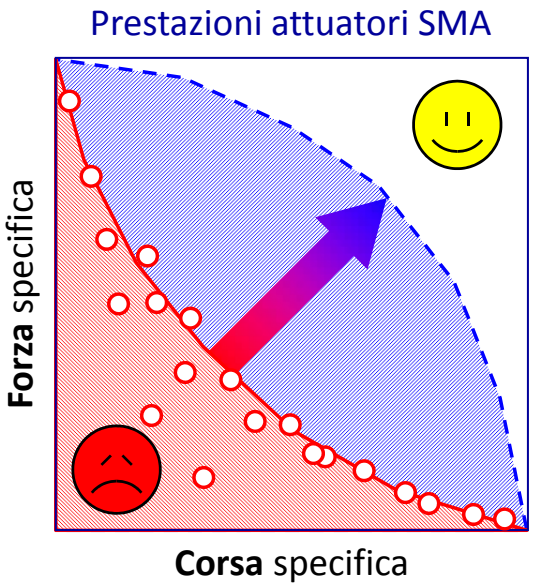
Modelli di comportamento meccanico



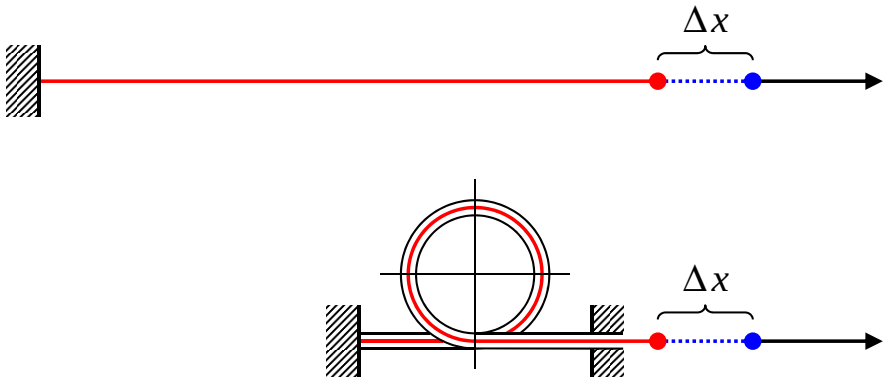
Attuatori non convenzionali



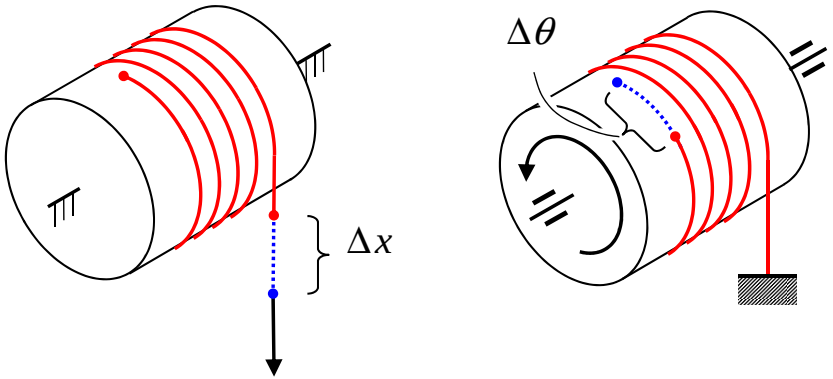
Attuatori non convenzionali



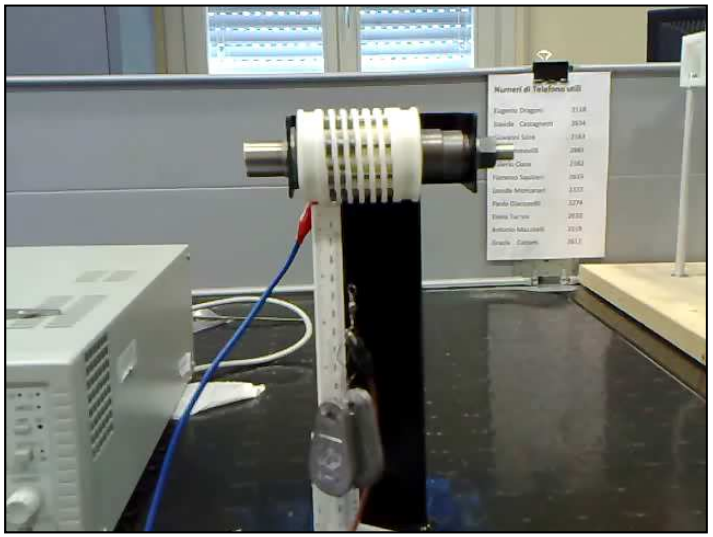
Attuatori non convenzionali



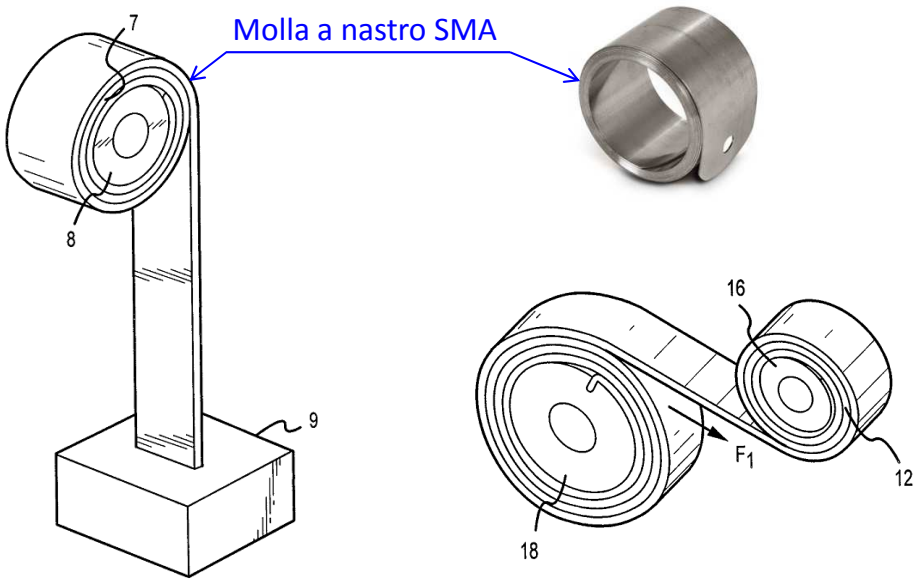
Attuatori non convenzionali



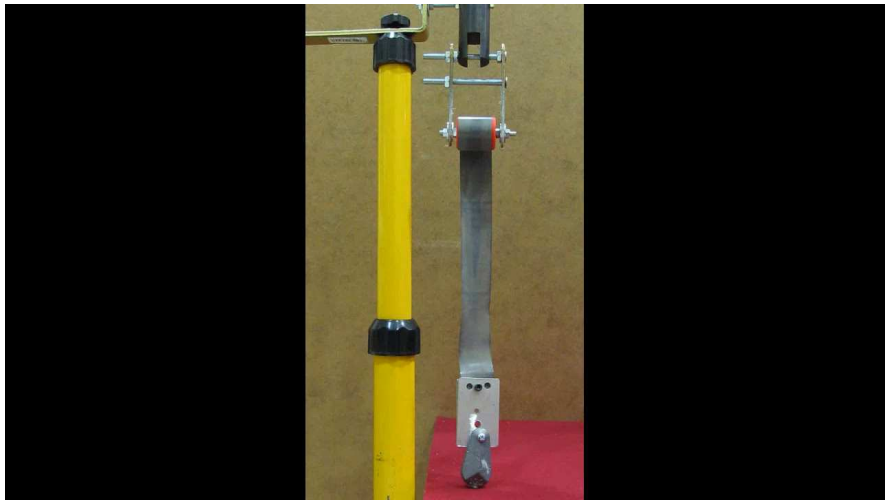
Attuatori non convenzionali



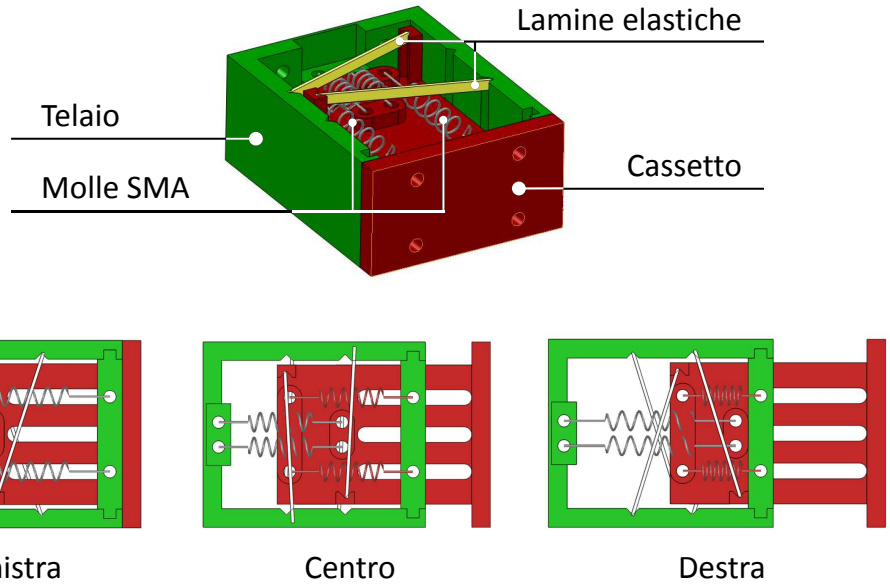
Attuatori non convenzionali



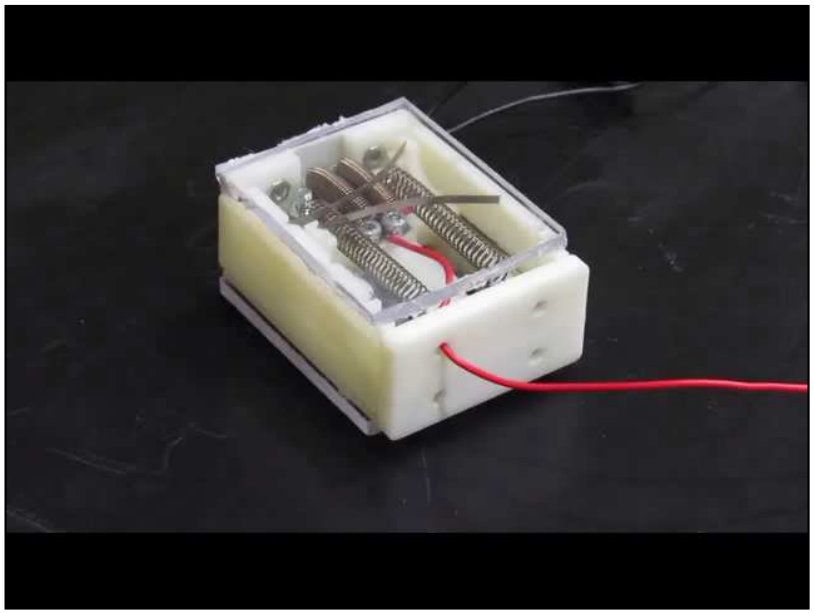
Attuatori non convenzionali



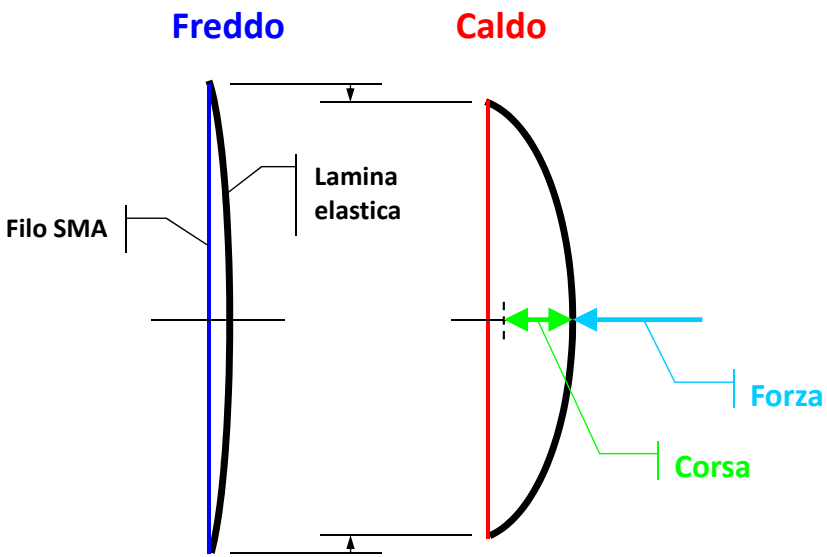
Attuatori non convenzionali



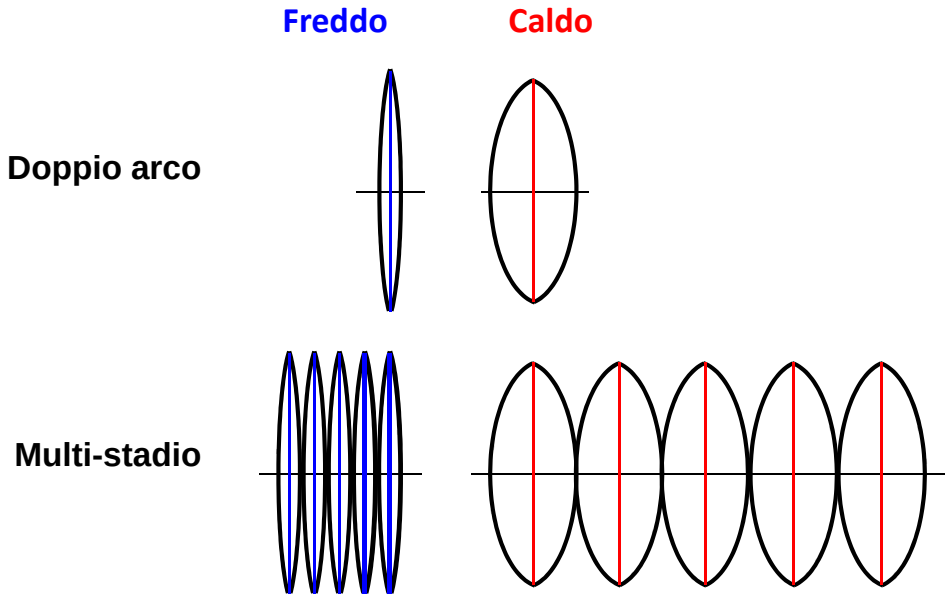
Attuatori non convenzionali



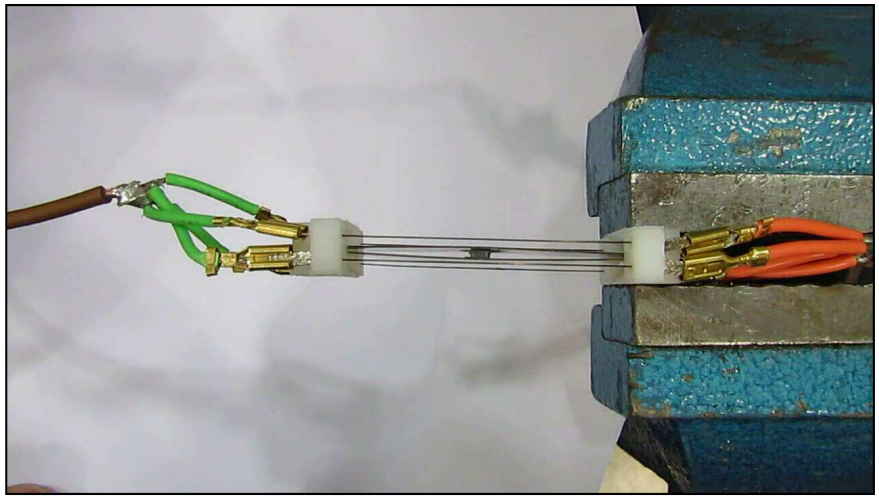
Attuatori non convenzionali



Attuatori non convenzionali



Attuatori non convenzionali



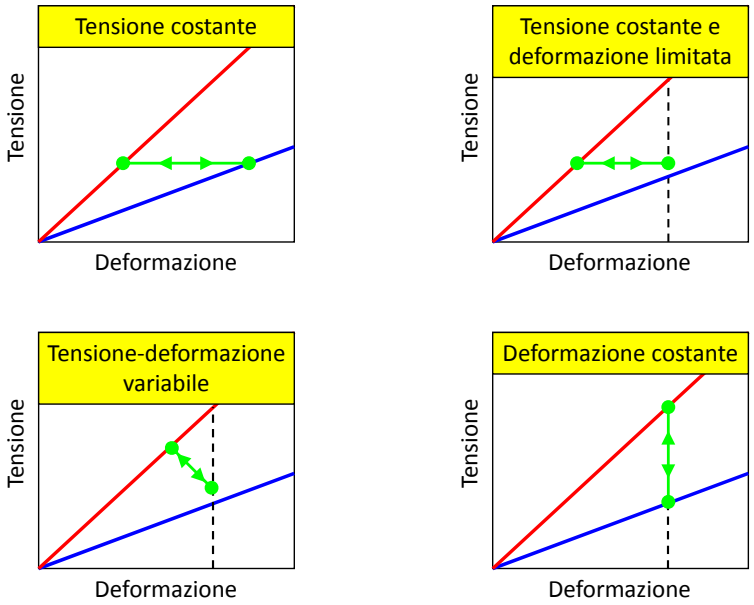
Fatica termomeccanica

Gli elementi SMA degli attuatori sono soggetti a ciclo termico

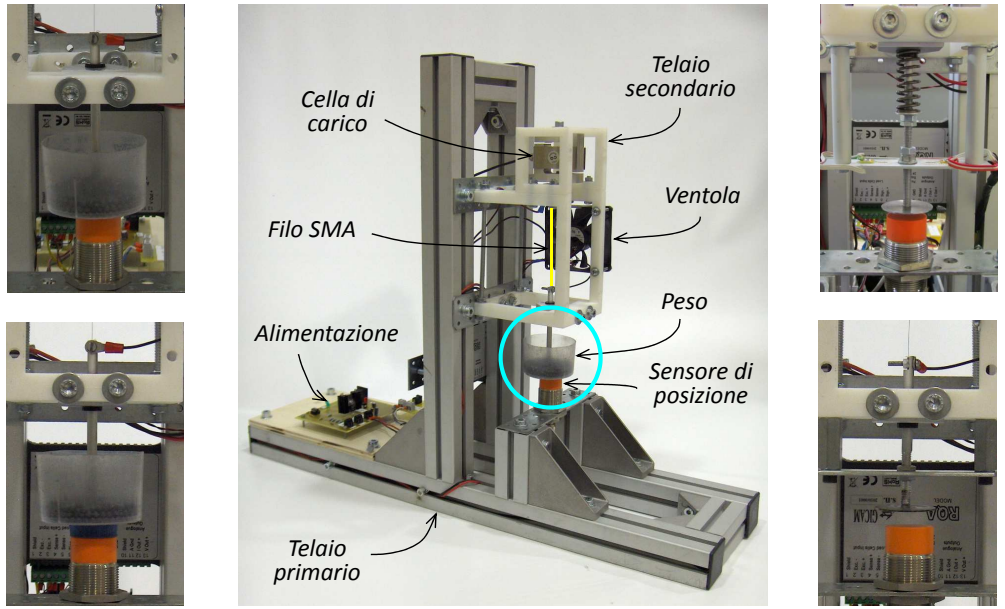
Nascono tensioni e deformazioni variabili nel tempo

Esiste pericolo di rottura o degrado funzionale per fatica termomeccanica

Fatica termomeccanica

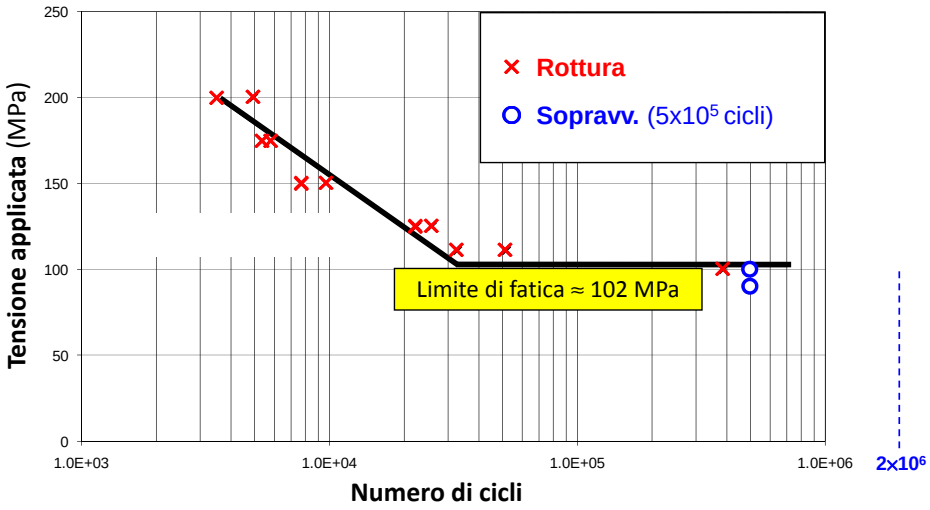


Fatica termomeccanica



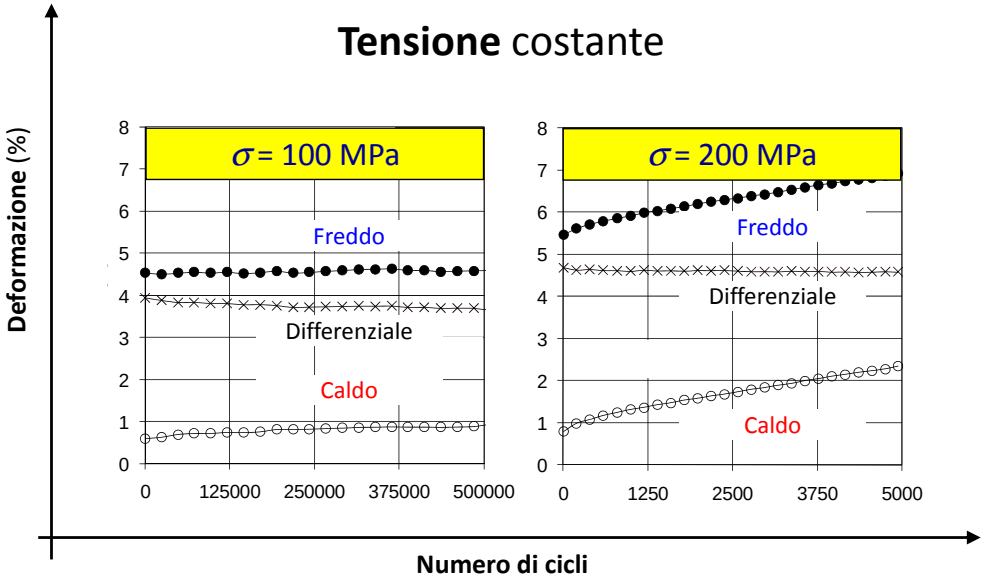
Fatica termomeccanica

Tensione costante



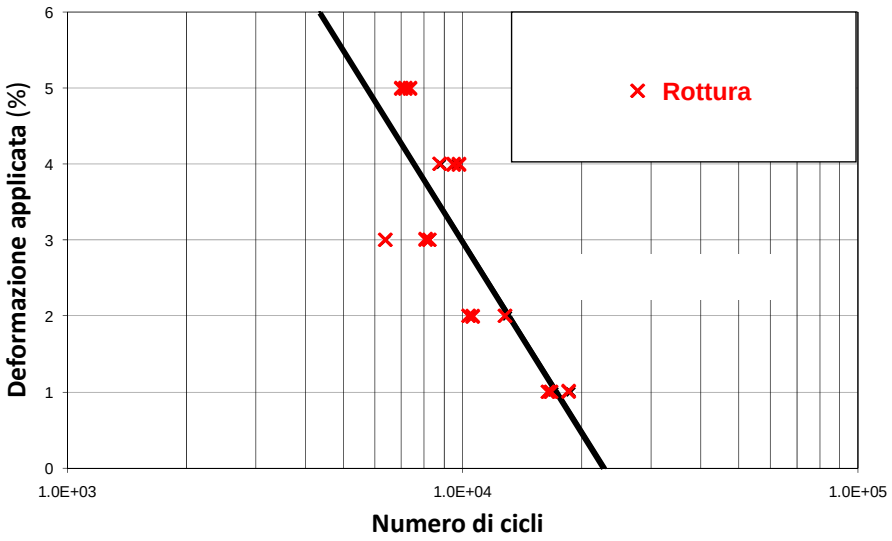
Fatica termomeccanica

Tensione costante



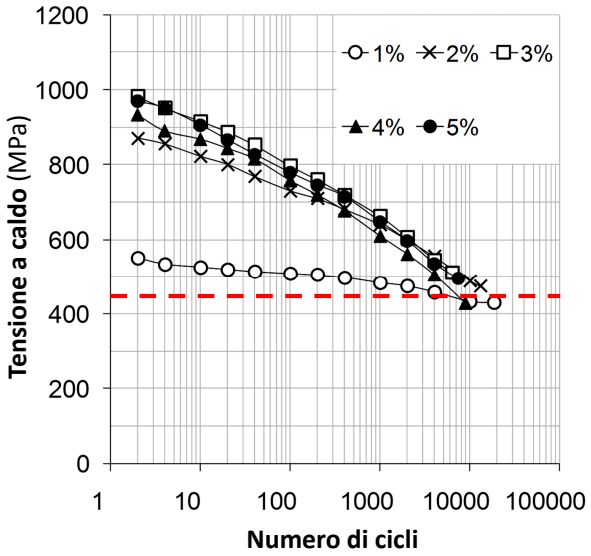
Fatica termomeccanica

Deformazione costante



Fatica termomeccanica

Deformazione costante



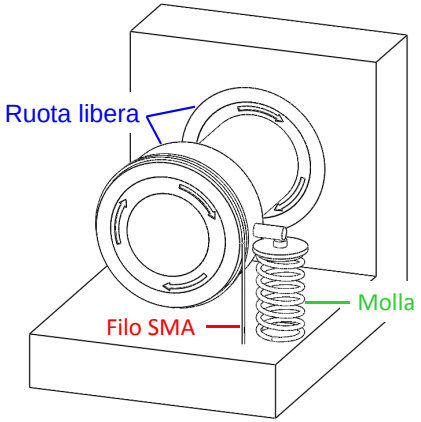
Linee di sviluppo

Motori angolari continui

Recupero energia a bassa entalpia

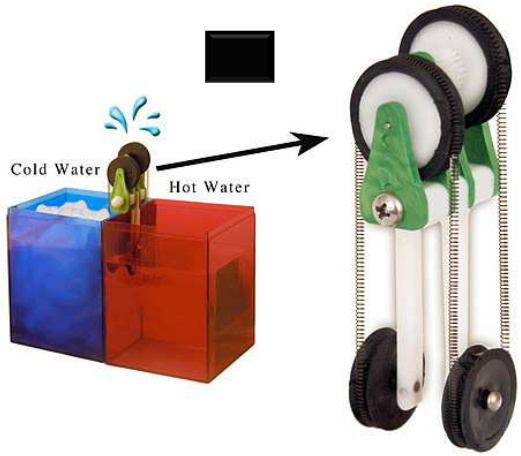
Linee di sviluppo

Motore angolare continuo



Linee di sviluppo

Recupero di energia a bassa entalpia



Conclusioni

La meccanica degli attuatori a memoria di forma è facile

Esistono semplici criteri di progettazione

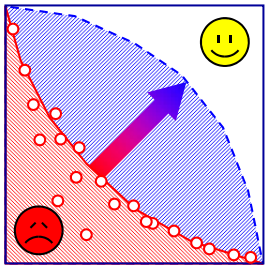
Le prestazioni dipendono dal sistema di riarmo

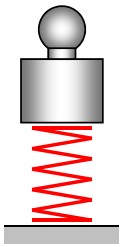
Le architetture non-convenzionali offrono vantaggi

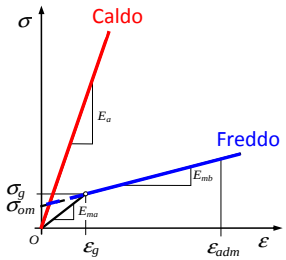
Servono dati su fatica strutturale e funzionale

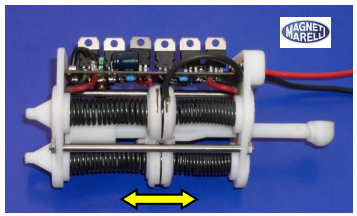
Promettente il recupero di energia a bassa entalpia

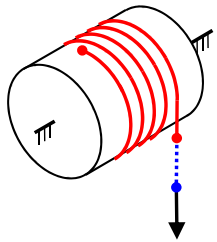
Domande?

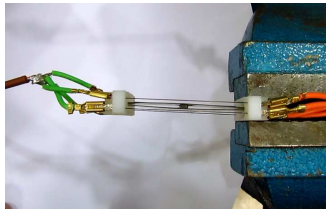












Bibliografia (1/2)

G. Scirè Mammano, E. Dragoni (In stampa) “Functional fatigue of Ni–Ti shape memory wires under various loading conditions”, *Int. J. Fatigue*, (http://www.sciencedirect.com/science/article/pii/S0142112312000874).

G. Scirè Mammano, E. Dragoni (In stampa) "Elastic compensation of linear shape memory alloy actuators using compliant mechanisms", *J. Intelligent Material Systems and Structures*, (doi: 10.1177/1045389X13488253).

A. Spaggiari, E. Dragoni (In stampa) " Analytical and numerical modeling of shape memory alloy Negator springs for constant-force, long-stroke actuators ", *J. Intelligent Material Systems and Structures*, (doi: 10.1177/1045389X13493354).

A. Spaggiari, I. Spinella, E. Dragoni (2013) “Design equations for binary shape memory actuators under arbitrary external forces”, *J. Intelligent Material Systems and Structures*, 24(6), 682-694.

G. Scirè Mammano, E. Dragoni (2013) “Design and testing of an enhanced shape memory actuator elastically compensated by a bistable rocker arm”, *J. Intelligent Material Systems and Structures*, 24(6), 704-716.

A. Spaggiari, G. Scirè Mammano, E. Dragoni (2012) " Optimum mechanical design of binary actuators based on shape memory alloys", in *Smart Actuation and Sensing Systems - Recent Advances and Future Chall.*, G. Berselli, R. Vertechy, G. Vassura (Eds). Intech, 3-34.

G. Scirè Mammano, E. Dragoni (2011) “Modelling of wire-on-drum shape memory actuators for linear and rotary motion”, J. Intelligent Material Systems and Structures, 22(11), 1129-1140.

A. Spaggiari, E. Dragoni (2011) “Multiphysics Modeling and Design of Shape Memory Alloy Wave Springs as Linear Actuators”, *ASME J Mechanical Design*, 133(6), 061008(1-8).

Bibliografia (2/2)

A. Spaggiari, I. Spinella, E. Dragoni (211) “Design of a Telescopic Linear Actuator Based on Hollow Shape Memory Springs”, J*. of Materials Engineering and Performance*, 20(4-5), pp.489-486.

G. Scirè Mammano, E. Dragoni (2011) “Increasing stroke and output force of linear shape memory actuators by elastic compensation”, *Mechatronics*, 21(3), 579-580.

I. Spinella, E. Dragoni, F. Stortiero (2010) “Modeling, Prototyping, and Testing of Helical Shape Memory Compression Springs With Hollow Cross Section”, *ASME J. Mech. Design*, 132(6), 061008 (9 pp).

I. Spinella, E. Dragoni, (2010) “Analysis and design of hollow helical springs for shape memory actuators”, J*. Intelligent Material Systems and Structures*, 21(1), 185-199.

I. Spinella, G. Scirè Mammano, E. Dragoni (2009) “Conceptual design and simulation of a compact shape memory actuator for rotary motion”, *J. of Materials Engineering and Performance*, 18(5-6), 638-648.

A. Bellini, M. Colli, E. Dragoni, (2009) “Mechatronic Design of a shape memory alloy actuator for automotive tumble flaps: a case study”, *IEEE Transactions on Industrial Electronics*, 56(7), 2644-2656.

I. Spinella, E. Dragoni, (2009) “Design equations for binary shape memory actuators under dissipative forces”, Proc. IMechE, Part C: *J. Mechanical Engineering Science*, 223(C3), 531-543.