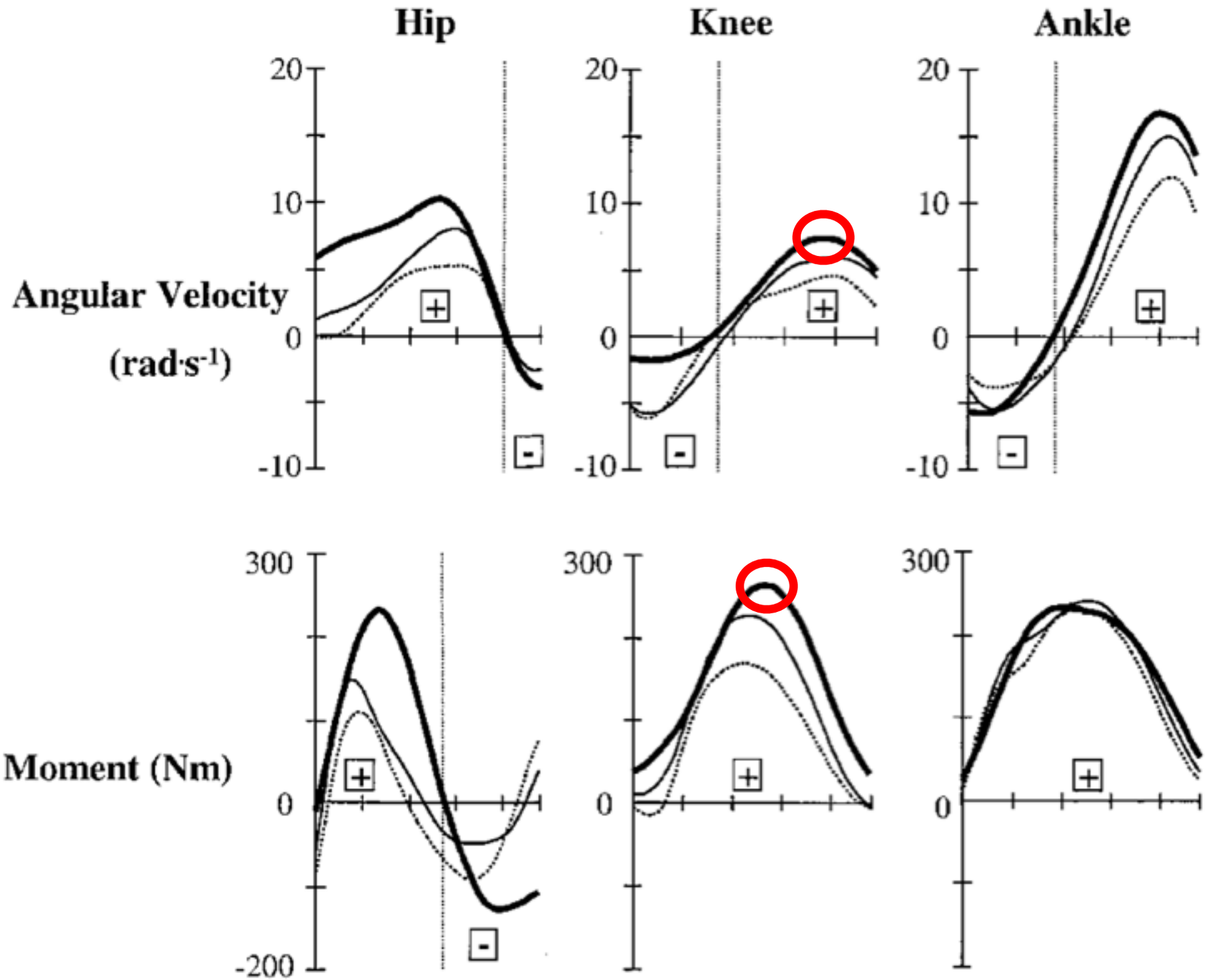
Biorobotik

Technische Aktuatoren

www.uni-stuttgart.de

Kinematik und Dynamik beim Rennen

Belli et al. 2002
Contact phase only

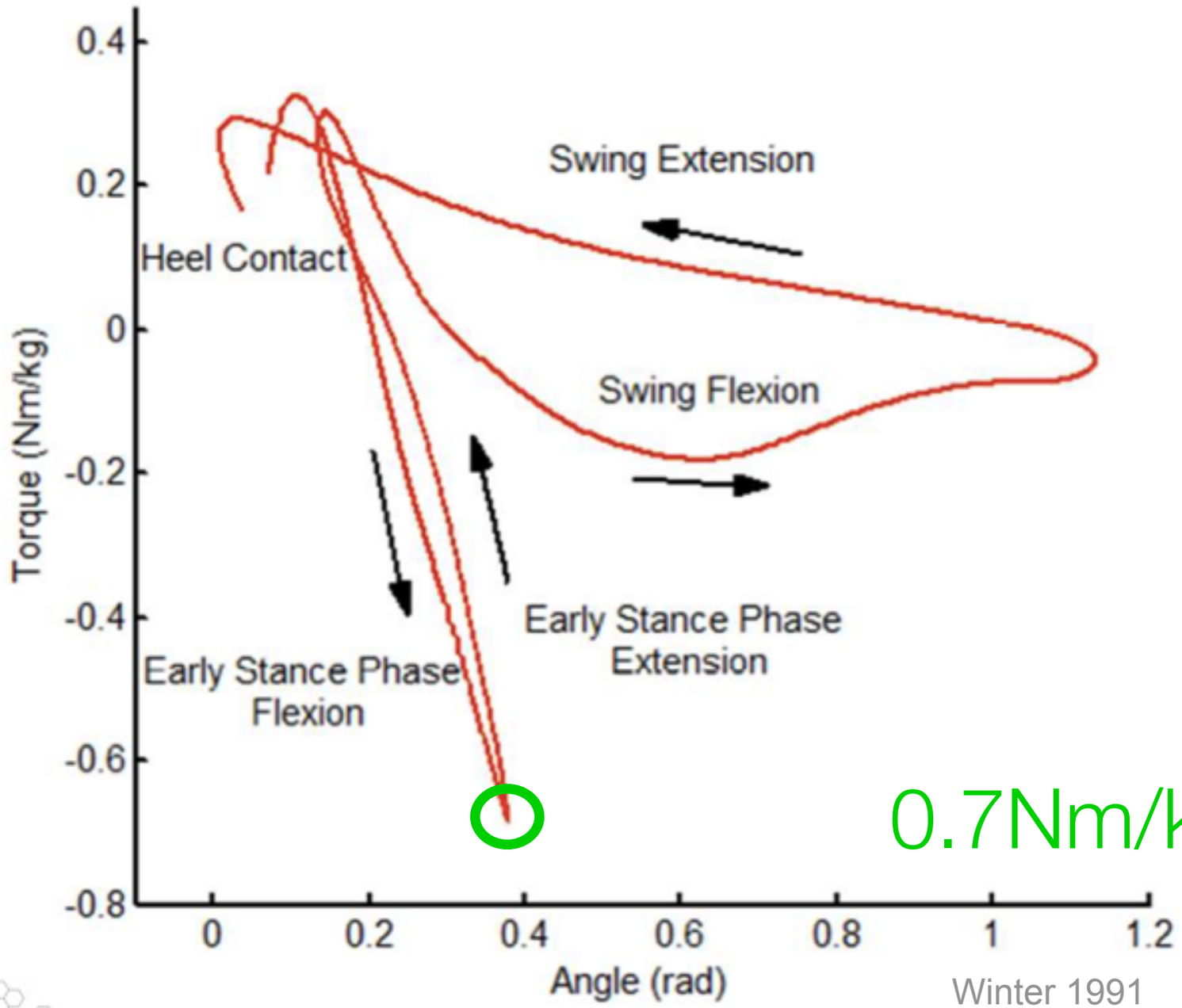


8 rad/s

280 Nm

www.uni-stuttgart.de

Kinematik und Dynamik beim Gehen



8 rad/s

0.7Nm/kg*70kg = 49 Nm

Winter 1991

inspo

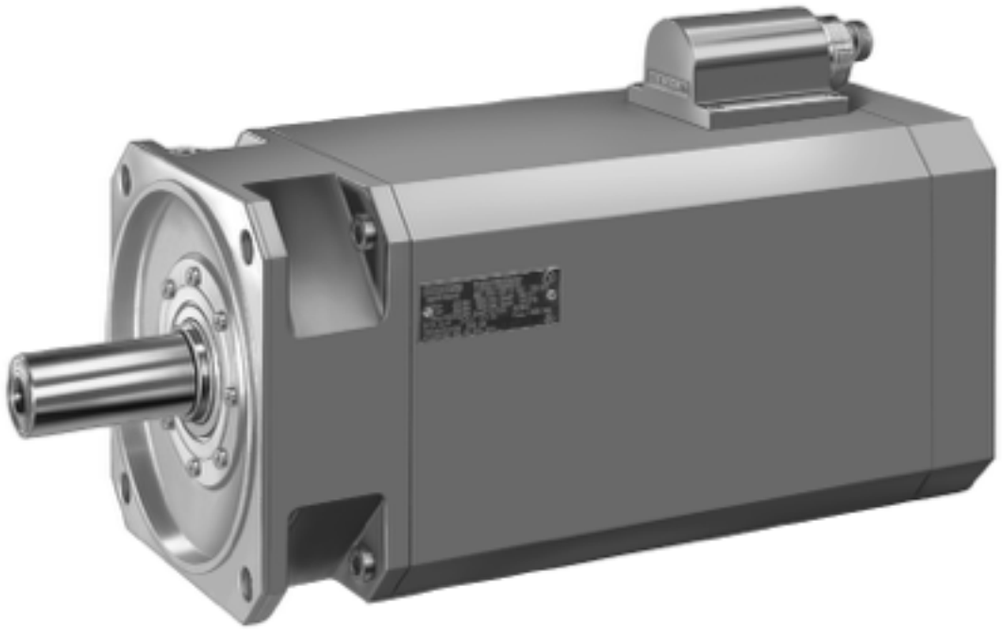
www.uni-stuttgart.de

Wahl des Aktuators

8 rad/s 280 Nm

8 rad/s 50 Nm

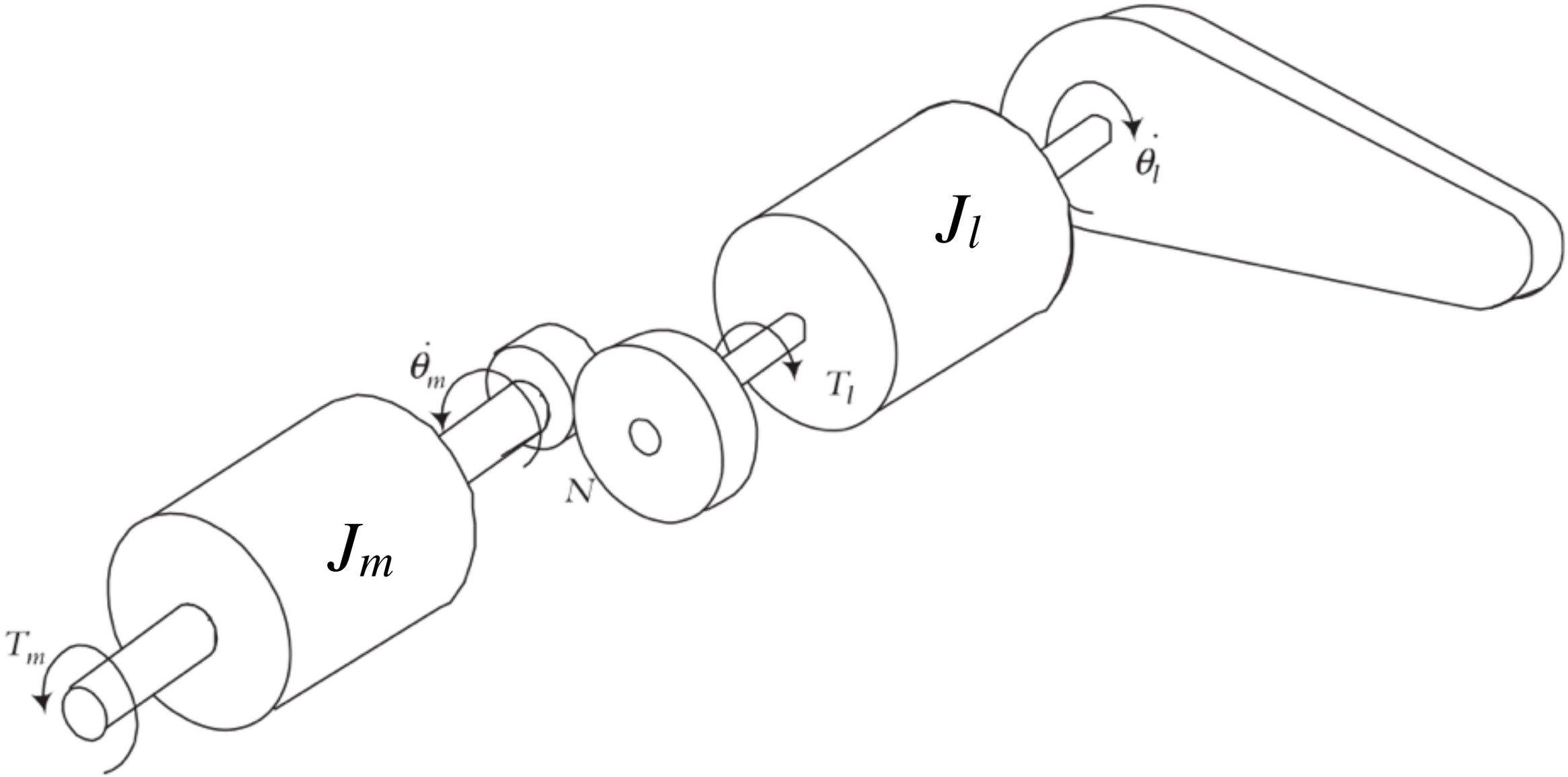
„Nissan Leaf wird von einem E-Motor mit 109 PS und 280 Nm in Bewegung gesetzt.“



SIEMENS 1FT6 three-phase servo motor
175 Nm
2000 U/min = 200 rad/s
123 kg

inspo

Schema eines Getriebes



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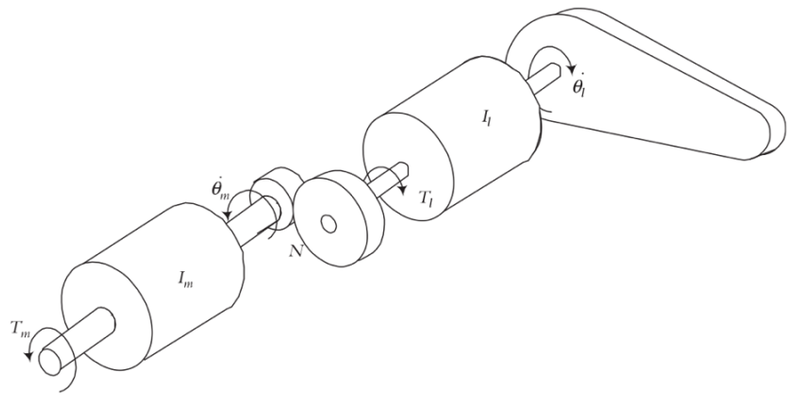
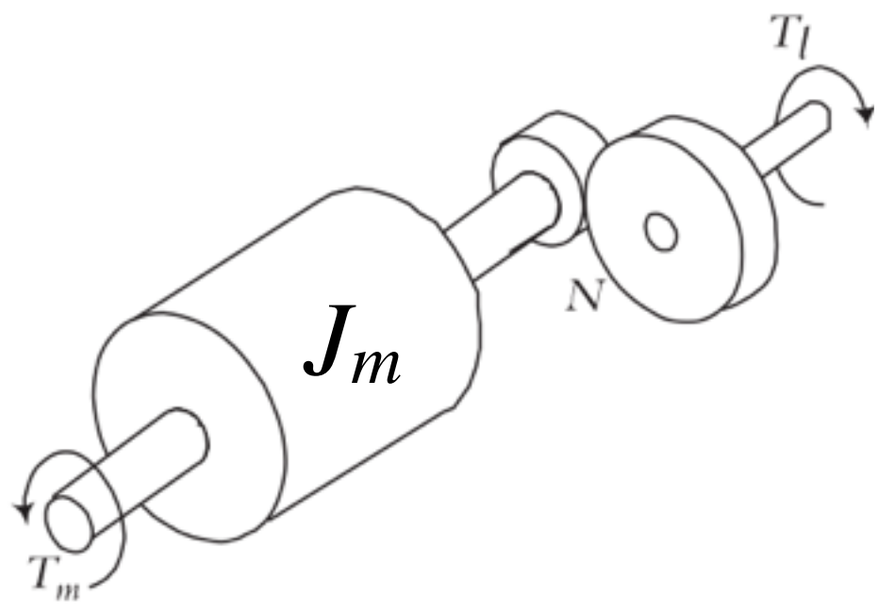
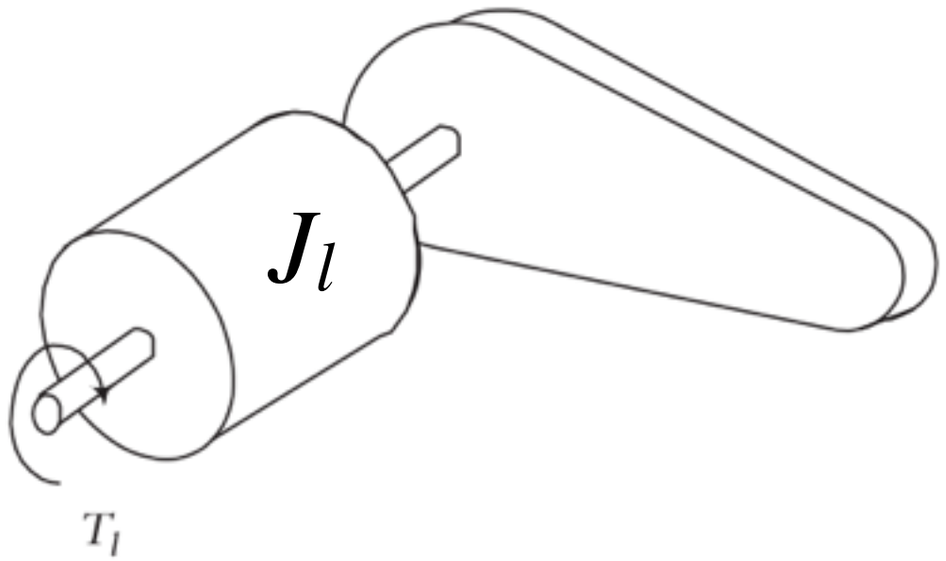
Freigeschnittenes Getriebe



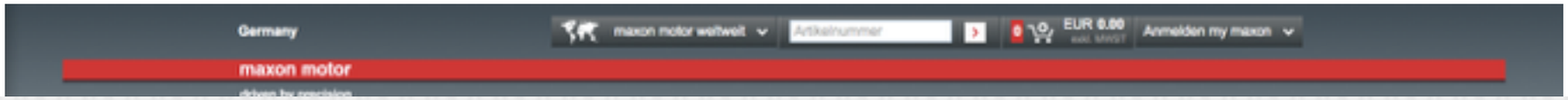


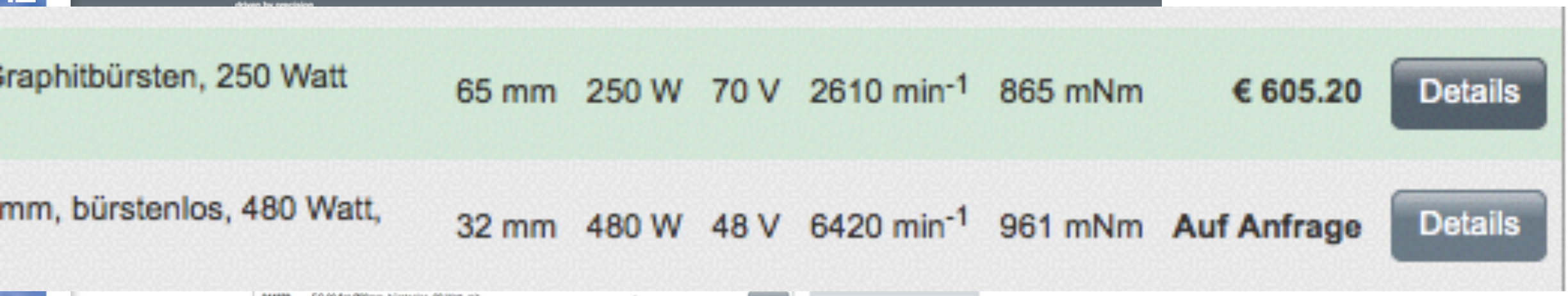


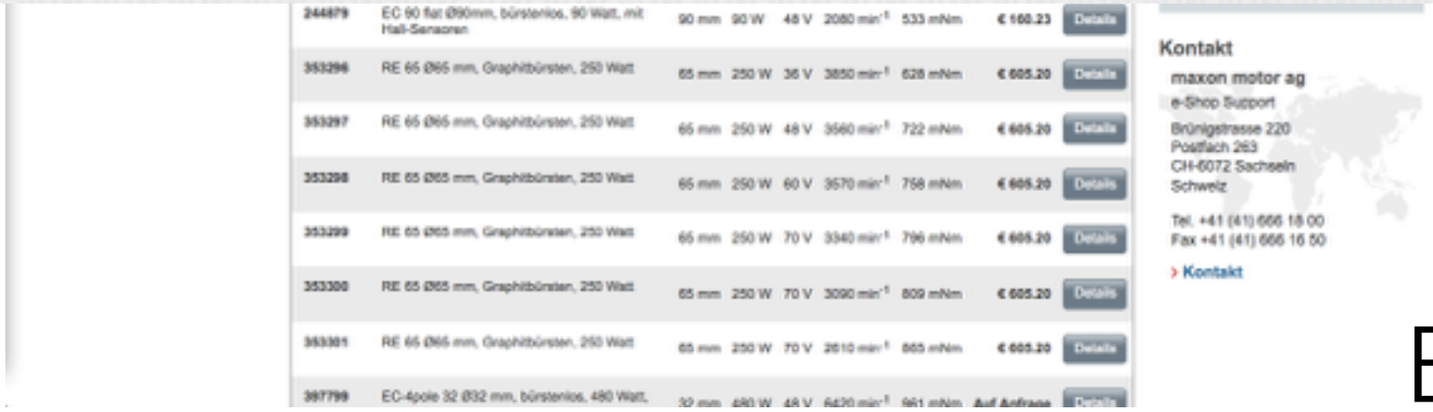
E-motor mit Getriebe: Maxon Katalog

8 rad/s 280 Nm

8 rad/s 50 Nm







Bürstenloser Motor+
51:1 Getriebe
m>5800g, ca. 1400Euro

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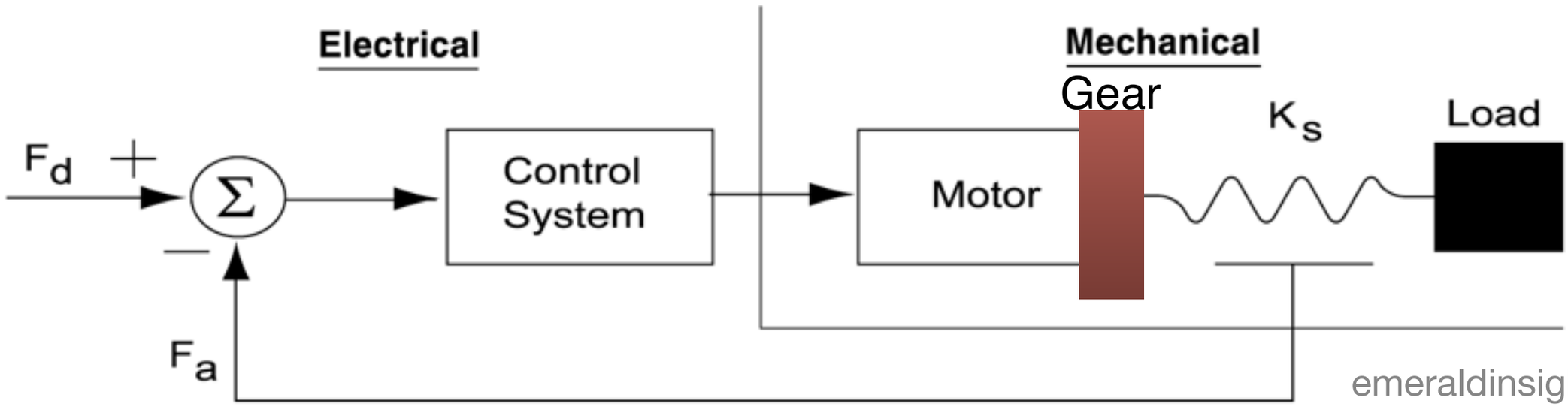
Seriell-Elastischer Aktuator (SEA)

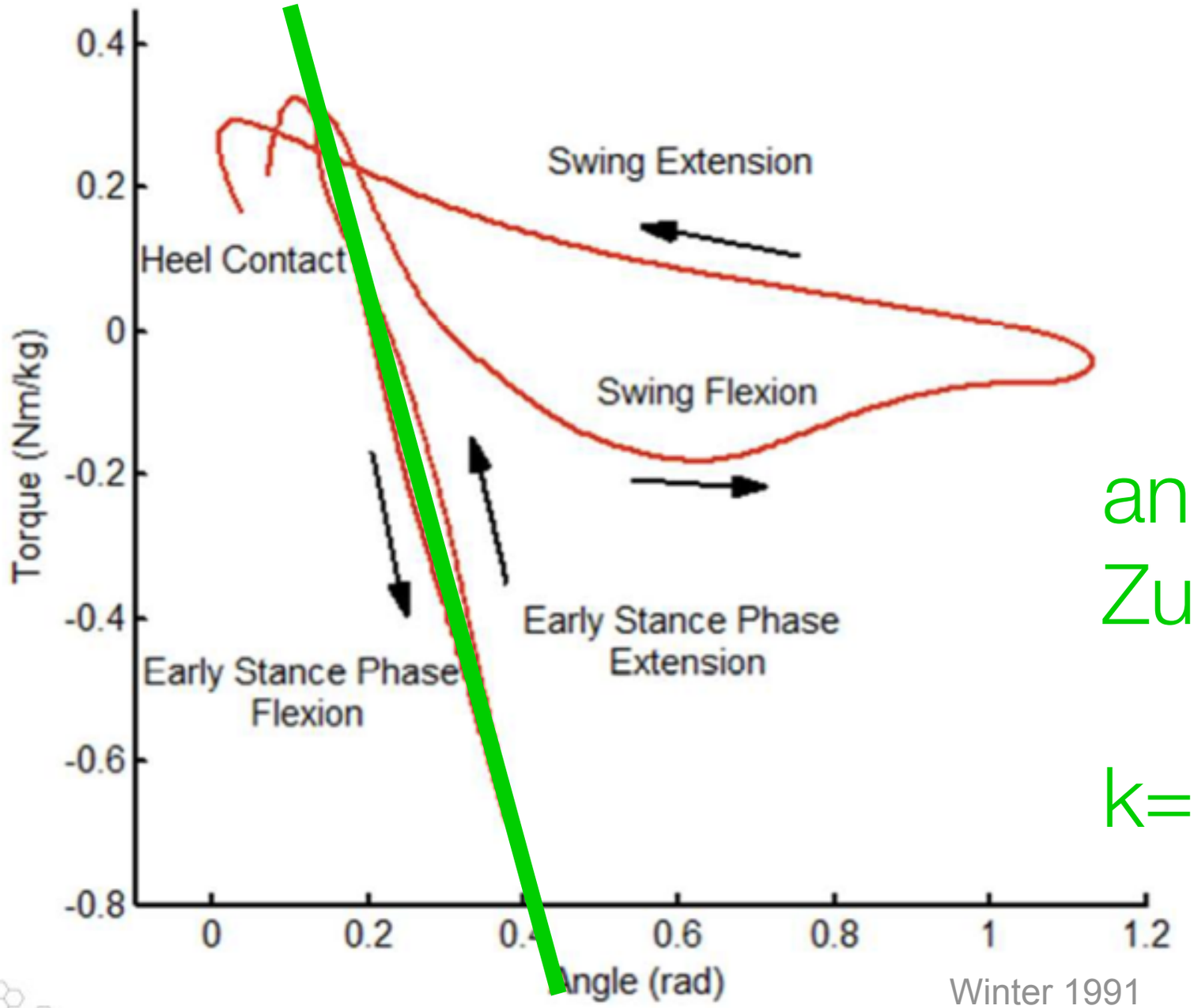
Kraftkontrolle eines SEA



emeraldinsight.com

www.uni-stuttgart.de

Kniesteifigkeit beim Gehen



annähernd linearer Zusammenhang

k=1Nmkg/0.2rad

Winter 1991

inspo

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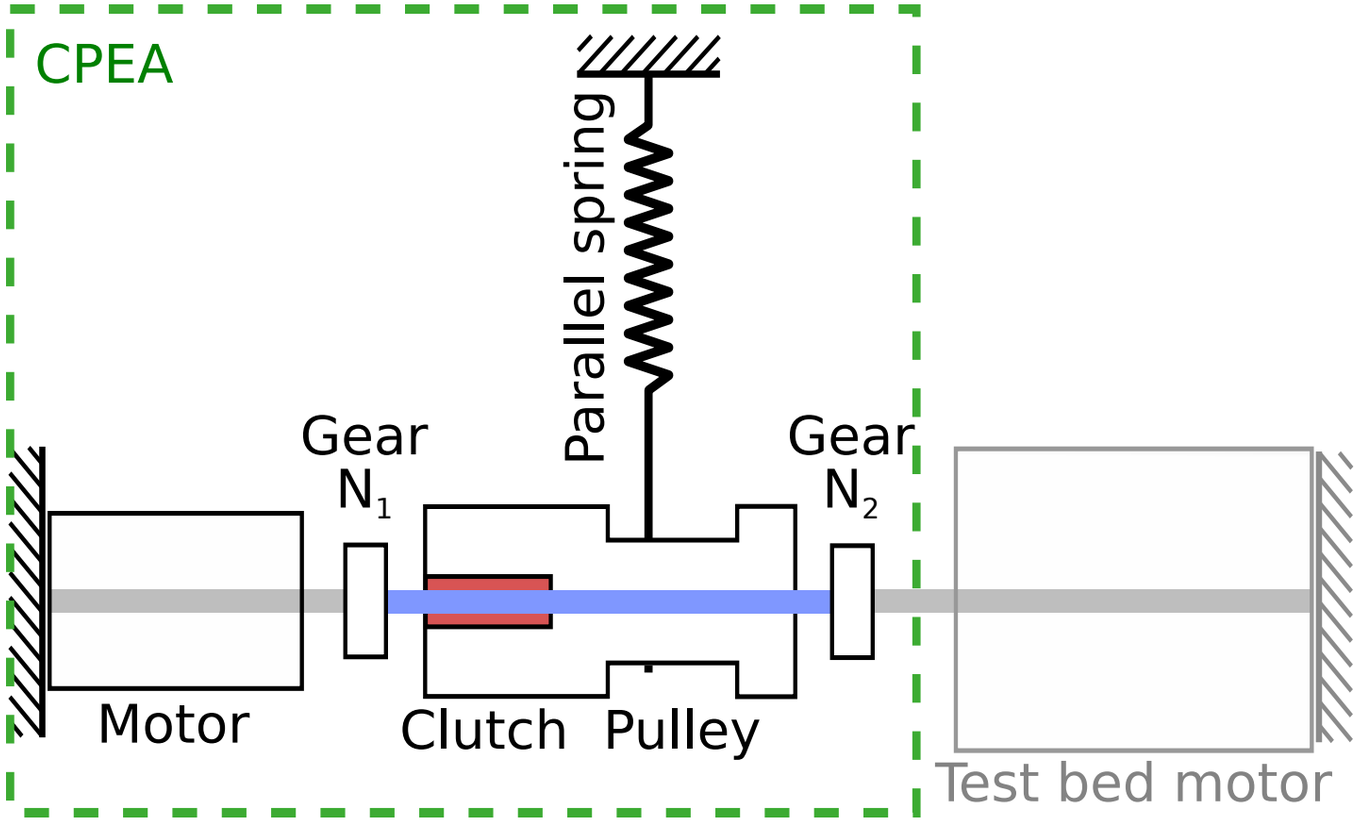
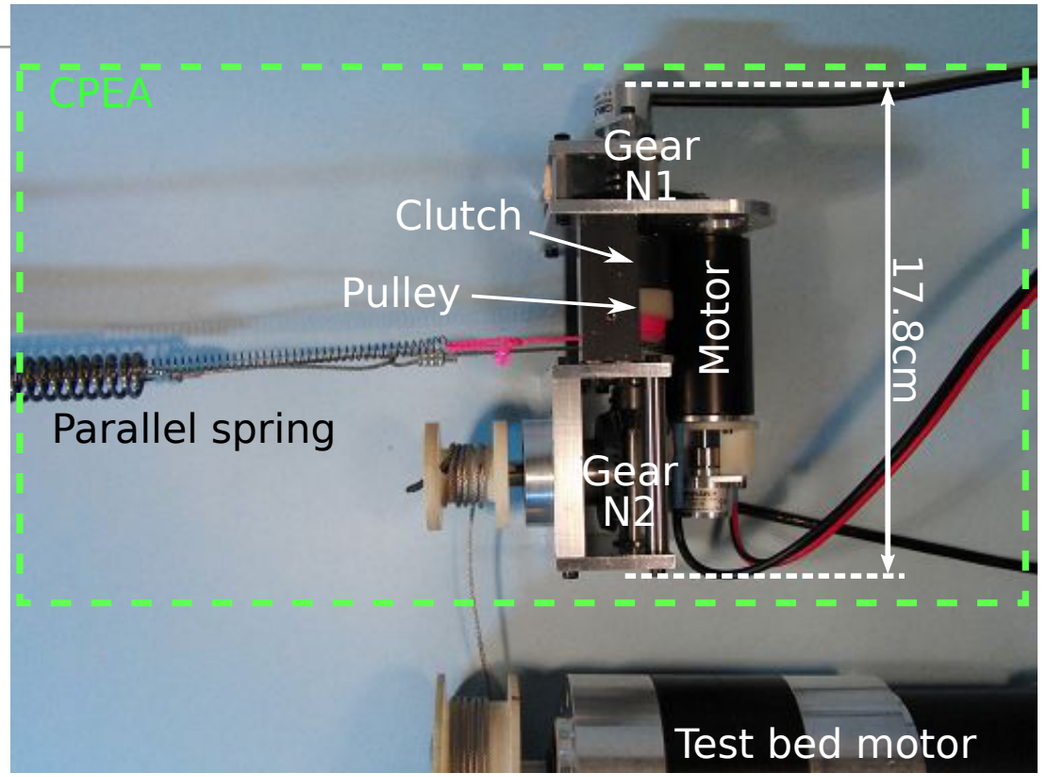
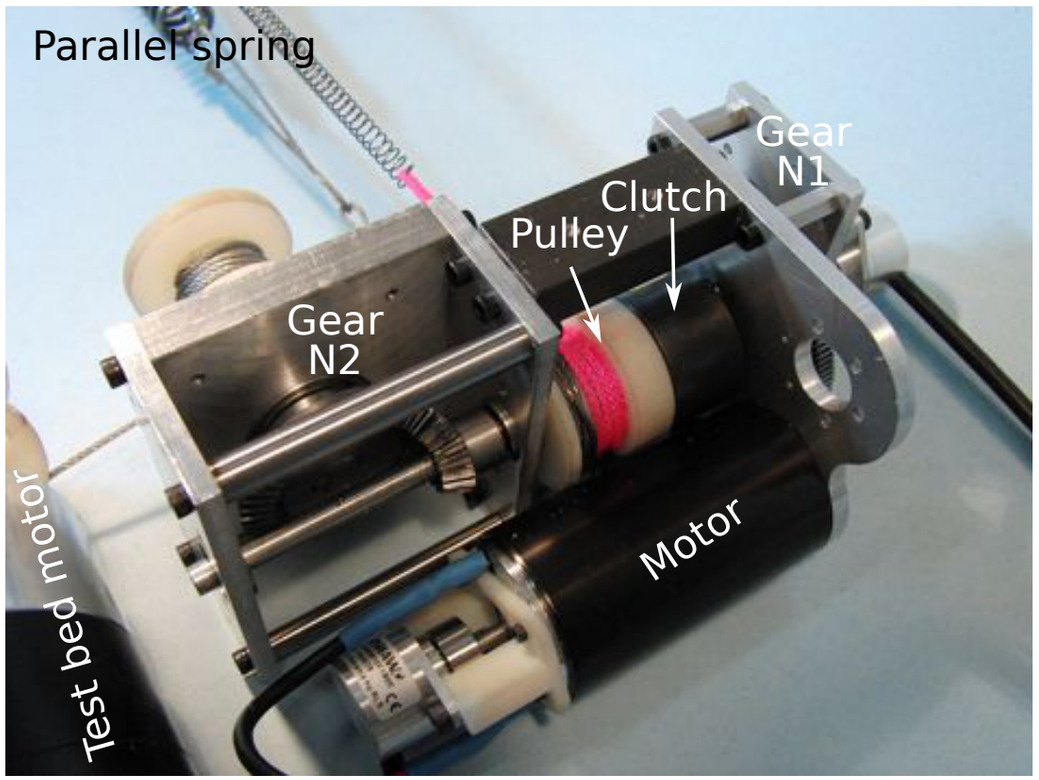
Clutched parallel elastic actuator CPEA

Haeufle et al. 2012







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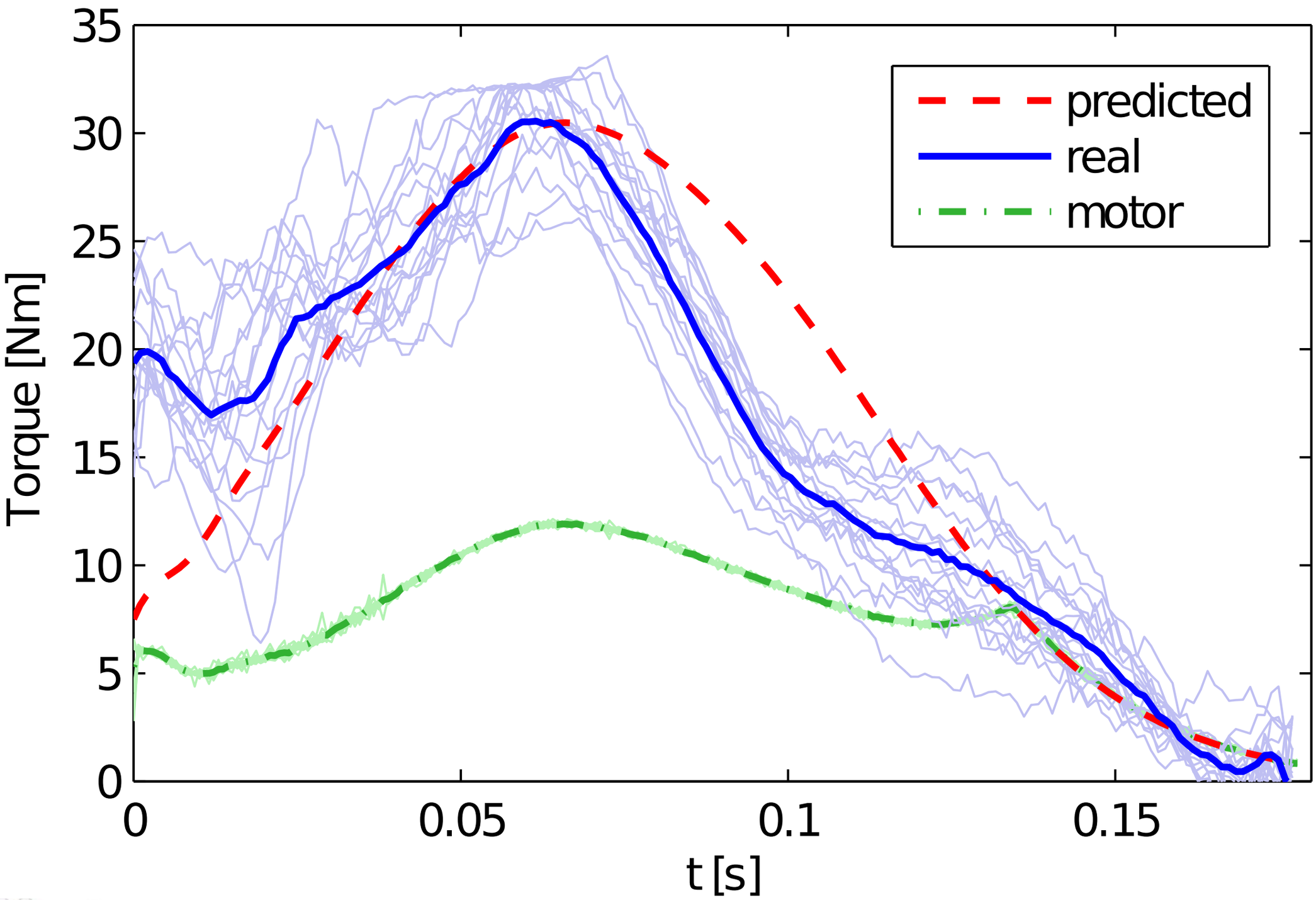
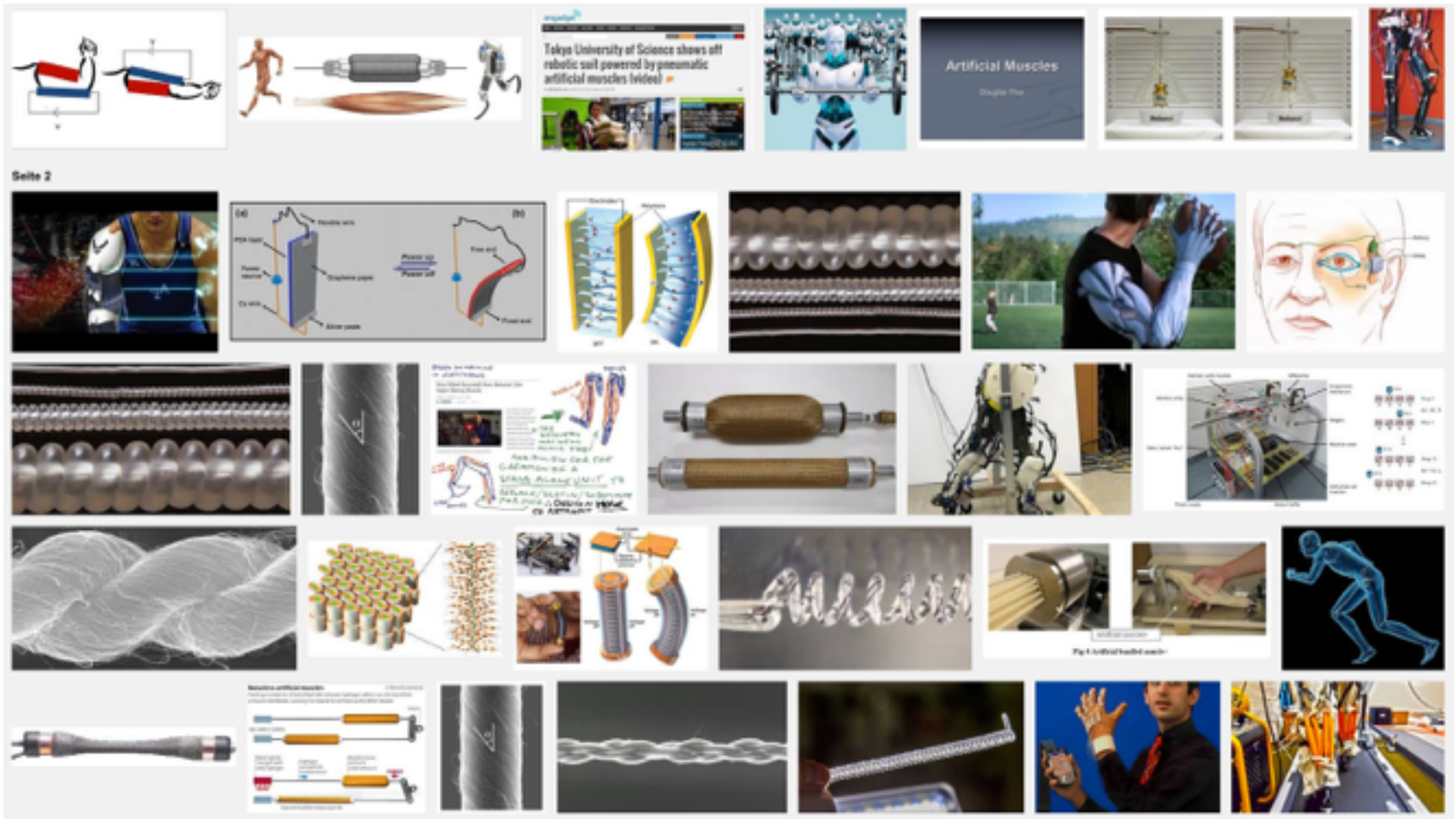
Clutched parallel elastic actuator CPEA

Haeufle et al. 2012



Künstliche Muskeln

„artificial muscles“
- 276 000 Ergebnisse bei google
- 16 200 bei google scholar



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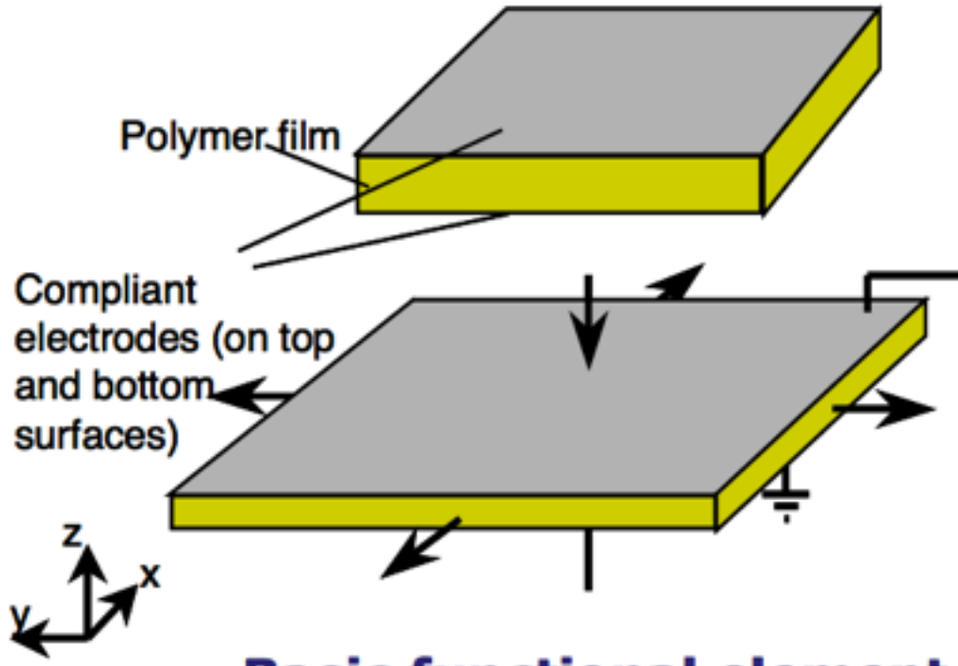
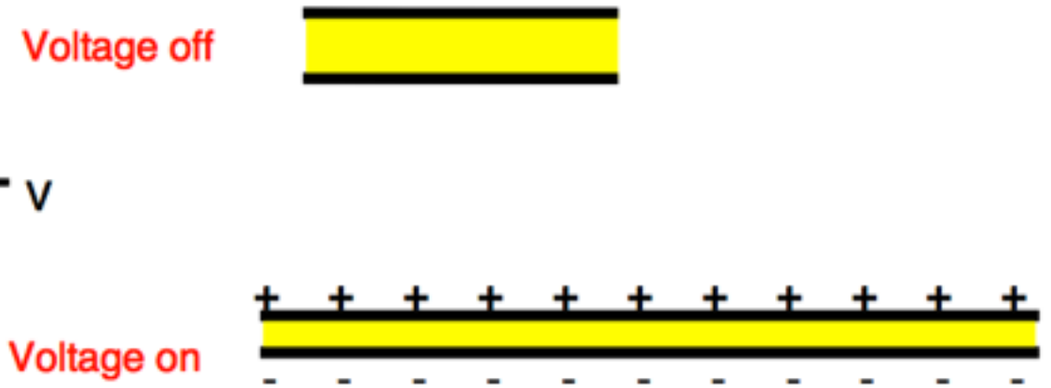
Dielektrische Elastomere

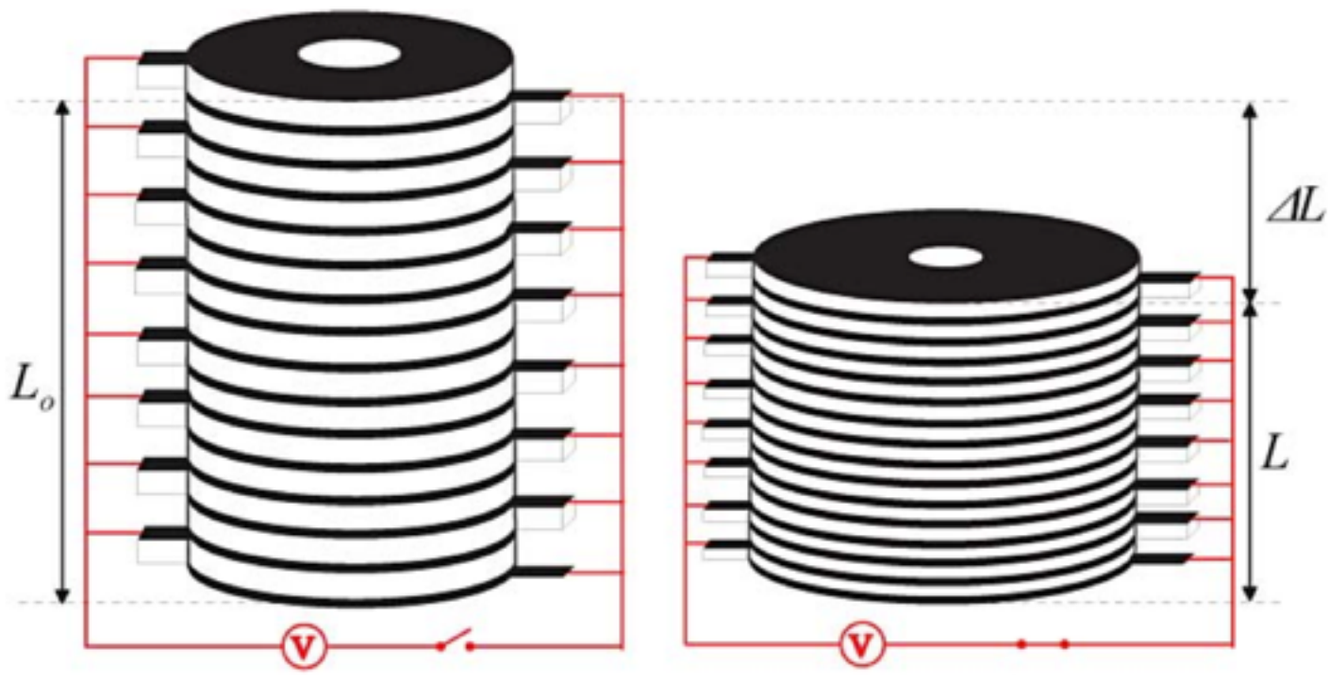


Basic functional element



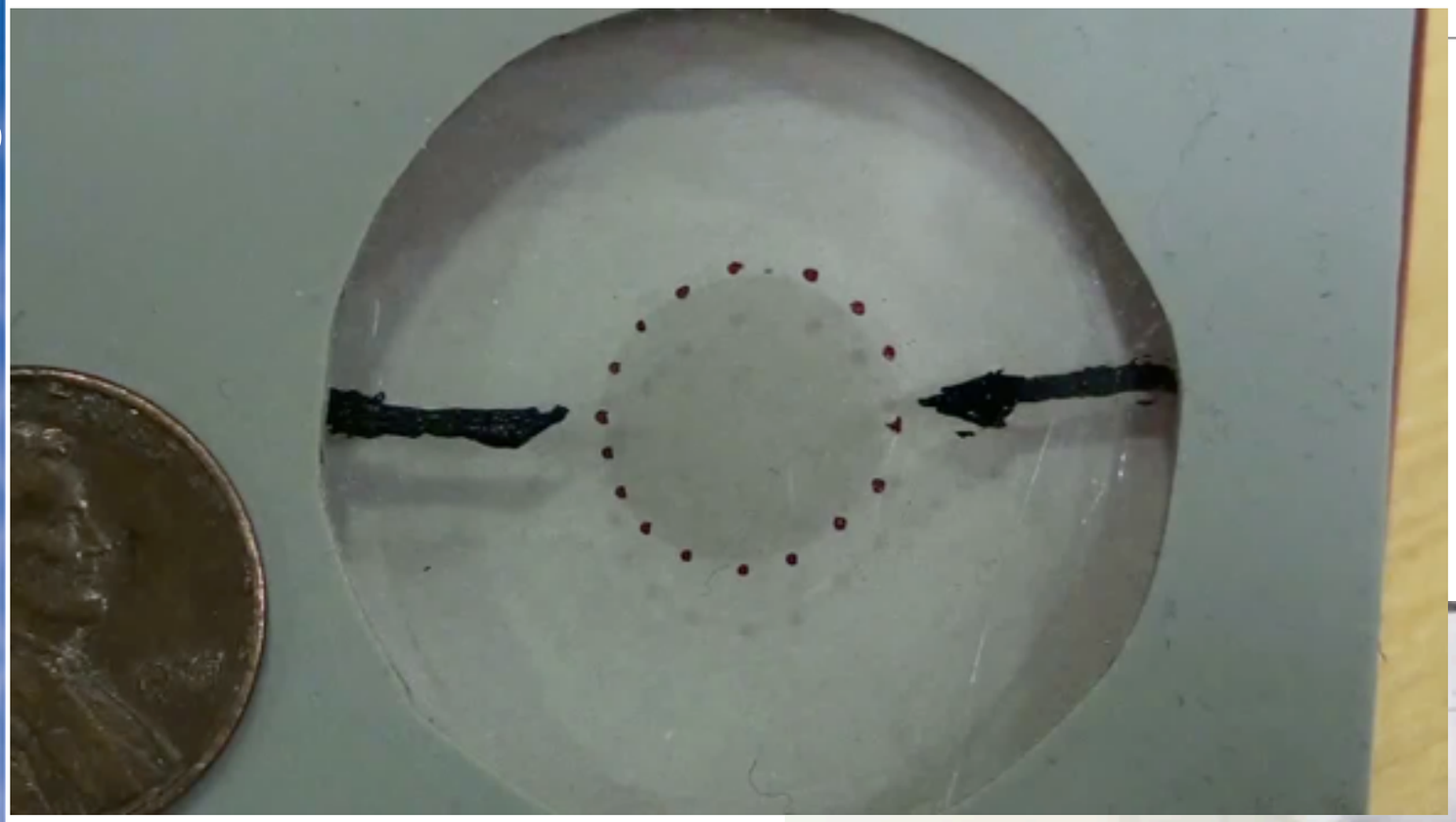
Pelrine et al. 2002

$$p = -\varepsilon\, \varepsilon_0 (V/d)^2$$

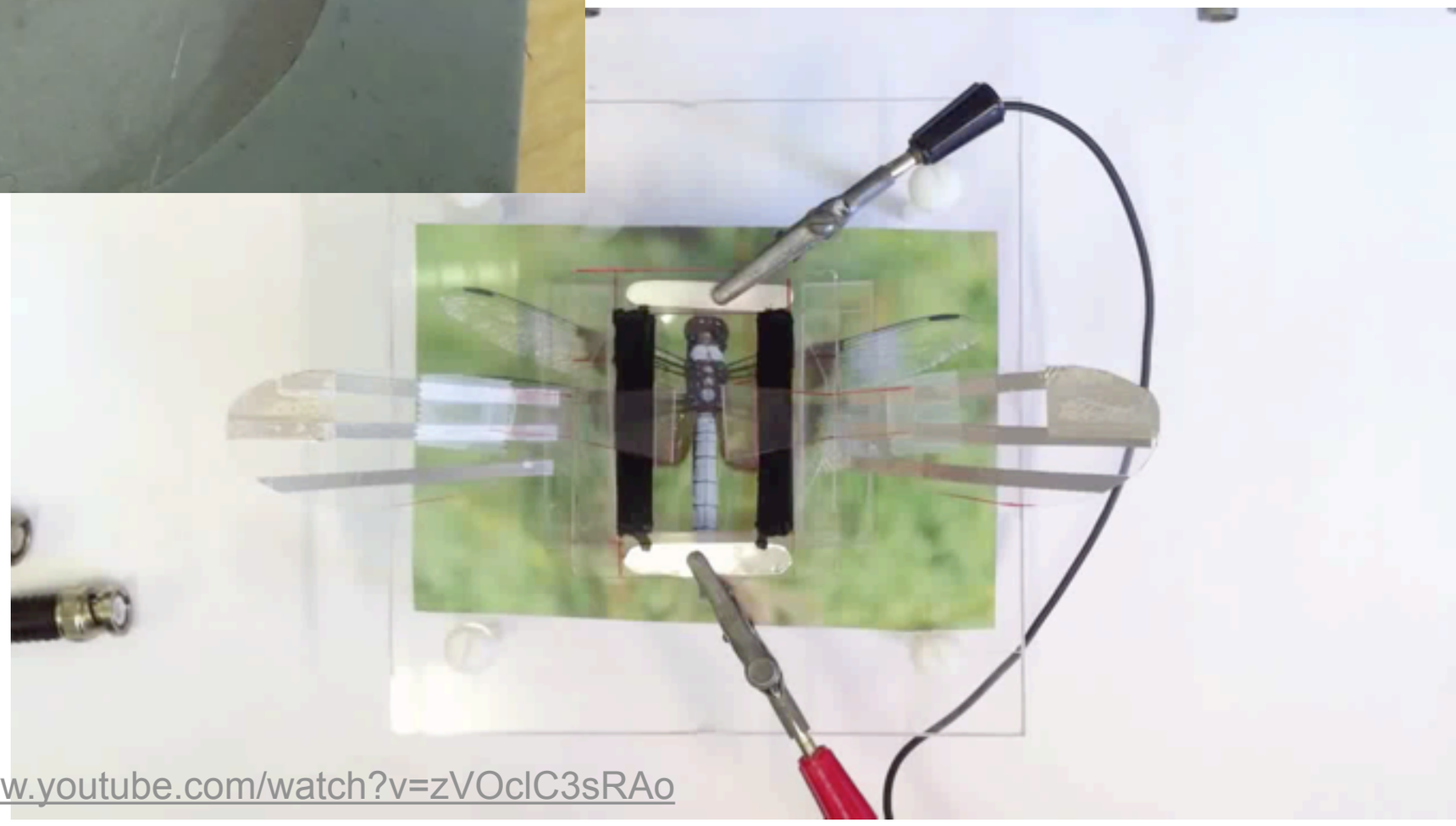


Chuc et al. 2011

Dielektrische Elastomere



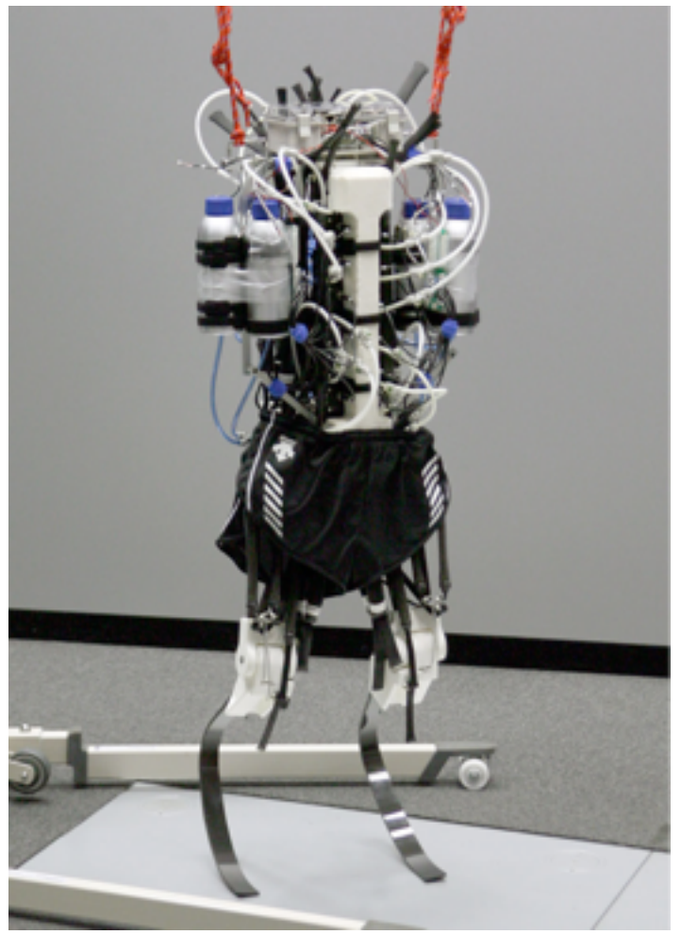
http://www.youtube.com/watch?v=6raGOHcgDNI



http://www.youtube.com/watch?v=zVOclC3sRAo

Pneumatische Muskeln „McKibben Muscles“

Villegas et al. 2012



ryuma niiyama: athlete robot

$$F = pl_0^2 \frac{n}{2\pi} \sin\left(\frac{2\pi}{n}\right) f\left(\epsilon, \frac{l_0}{R}\right)$$

Pneumatische Muskeln Festo

http://www.youtube.com/watch?v=2iG1ybuchx0

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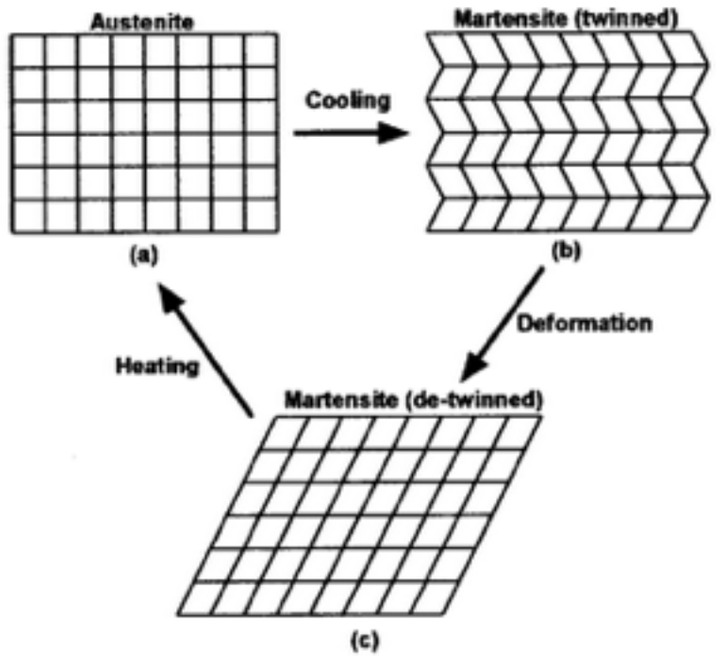
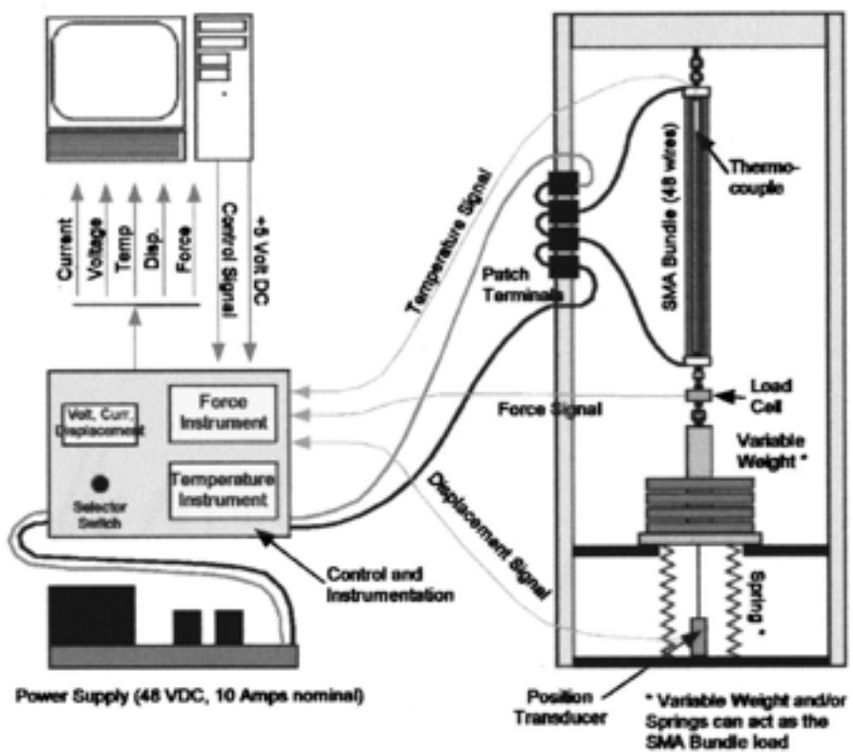
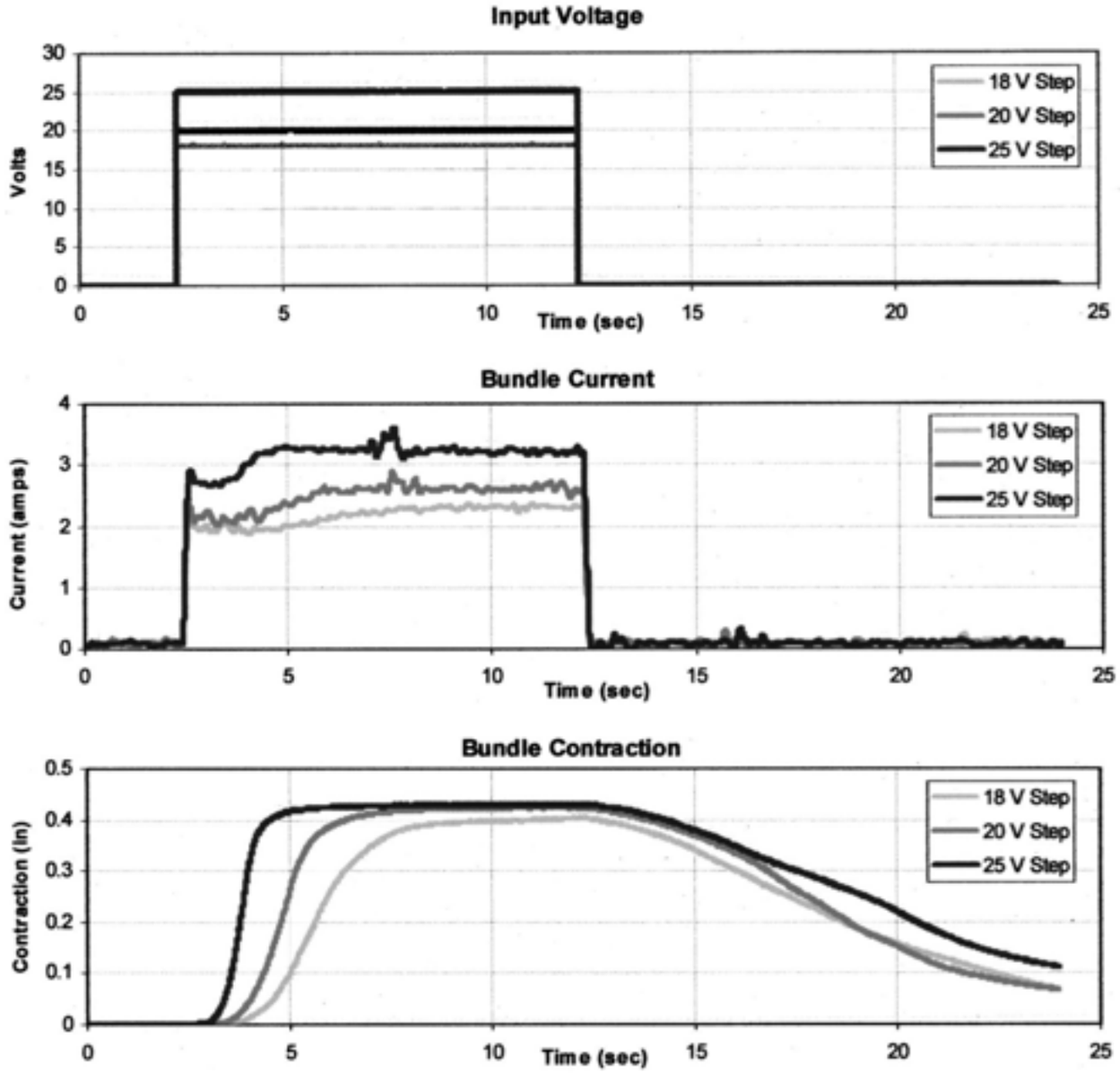
Formgedächtnis Legierungen

Mosley & Mavroidis 2001







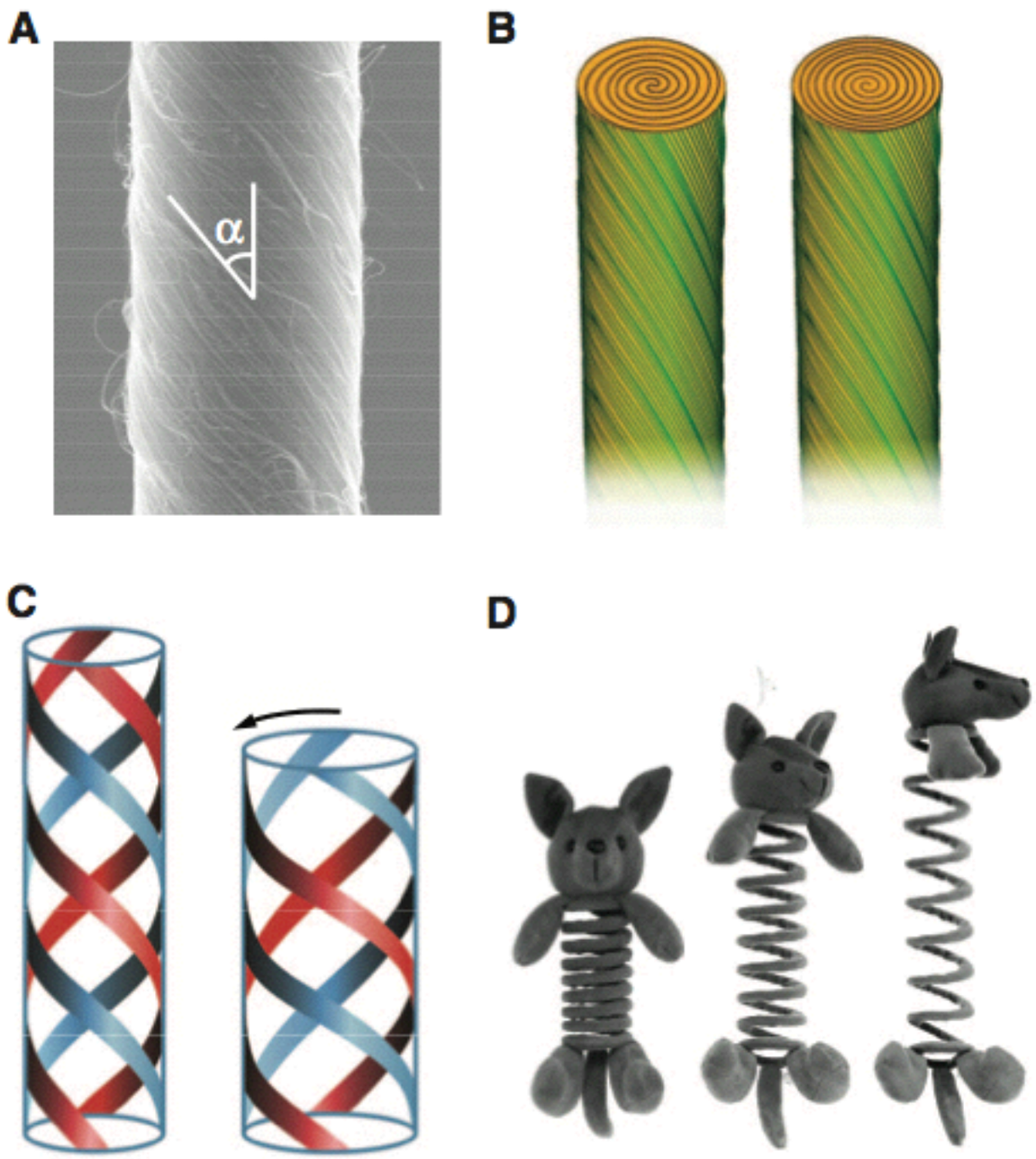
bei 5kg Last

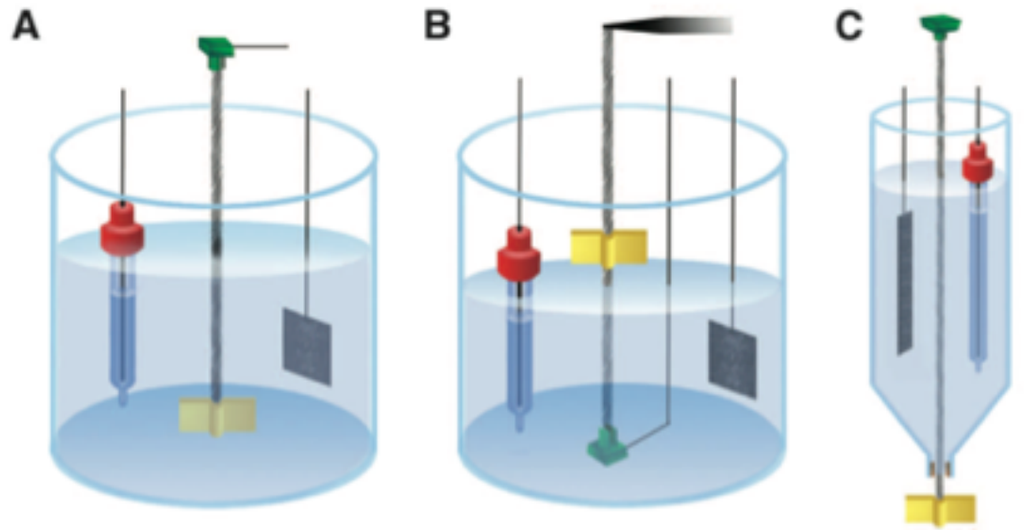
Formgedächtnis Legierungen

http://www.youtube.com/watch?v=gRFChxjNPK0

Torsional Carbon Nanotube Artificial Muscles

Foroughi et al. 2011



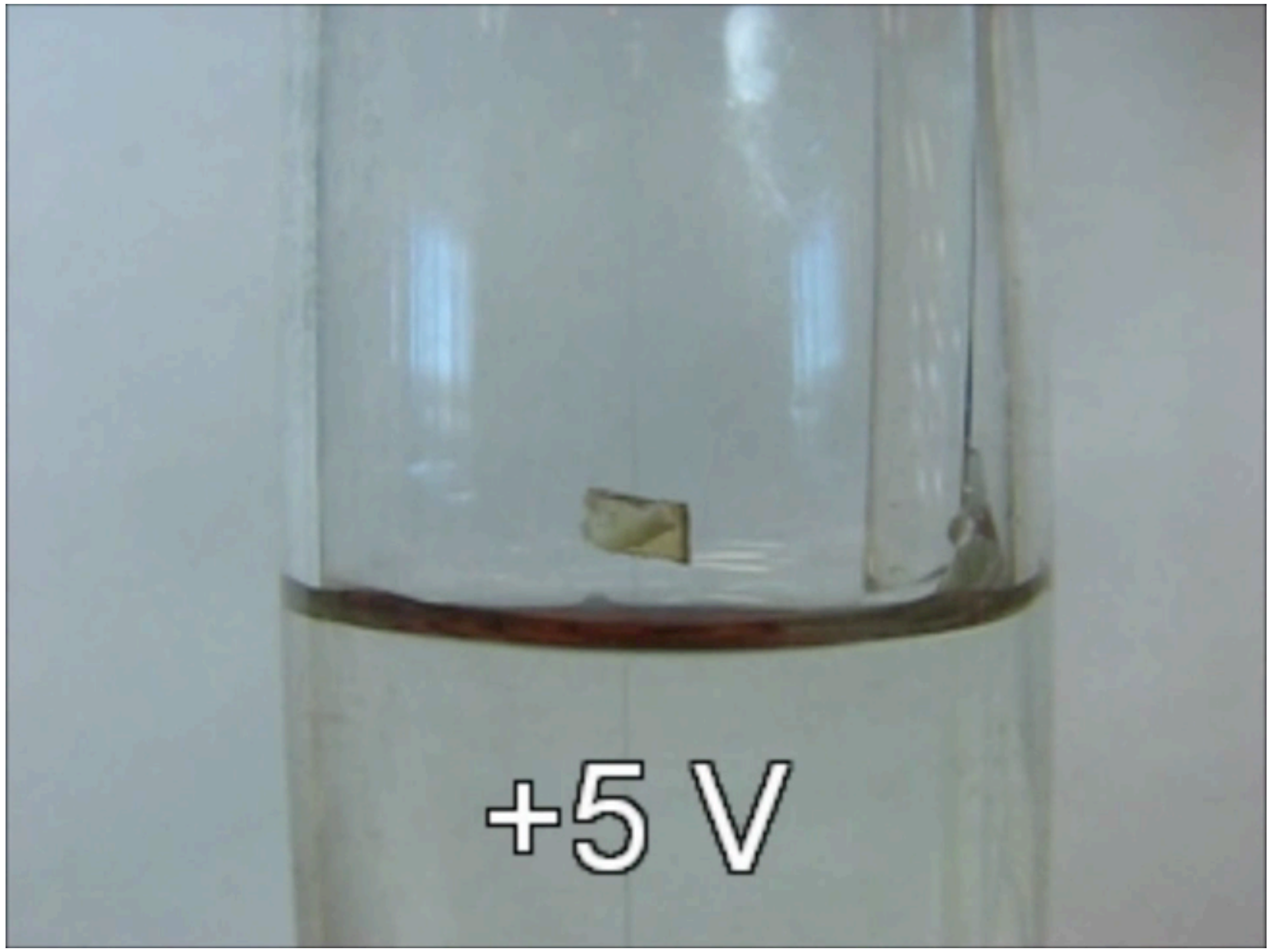


Hohe Rotationsgeschw. 590 U/min
Bis zu 15.000°
Kann sehr klein gebaut werden

inspo

Torsional Carbon Nanotube Artificial Muscles

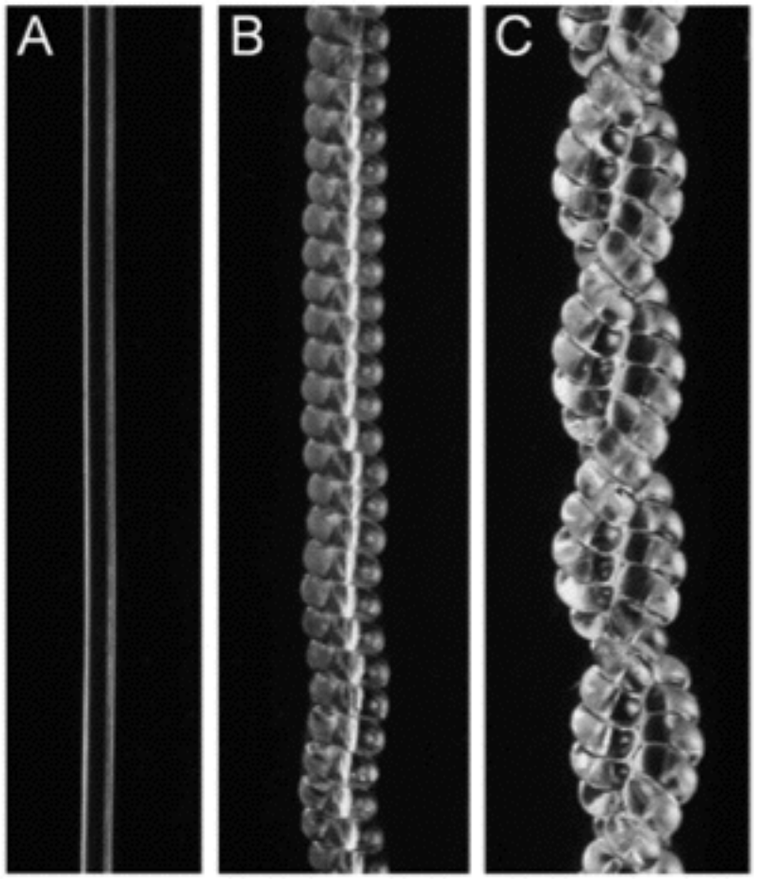
Foroughi et al. 2011

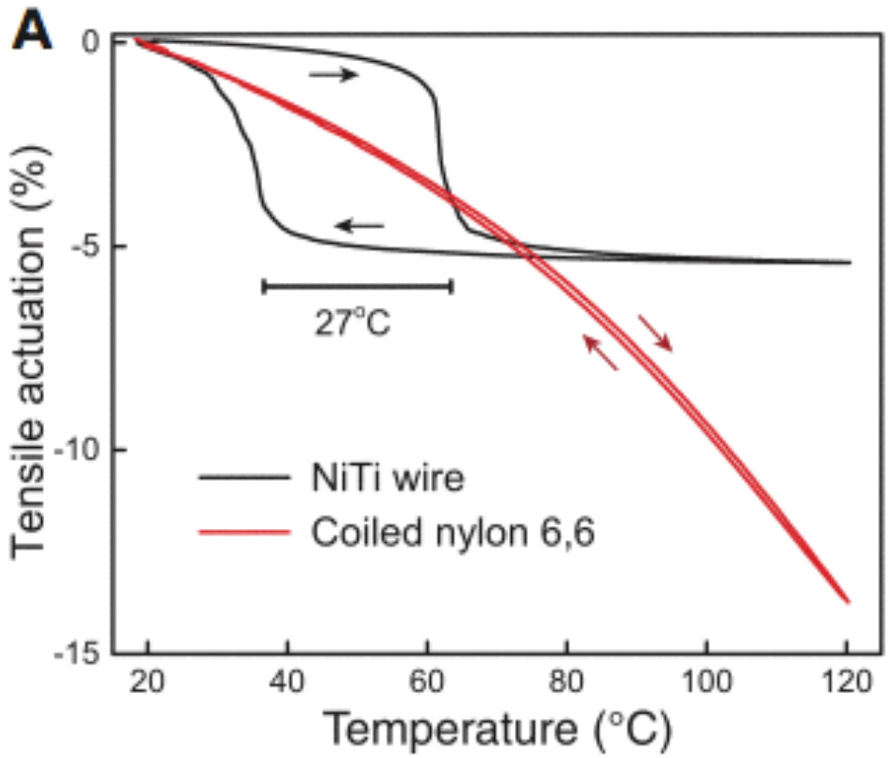


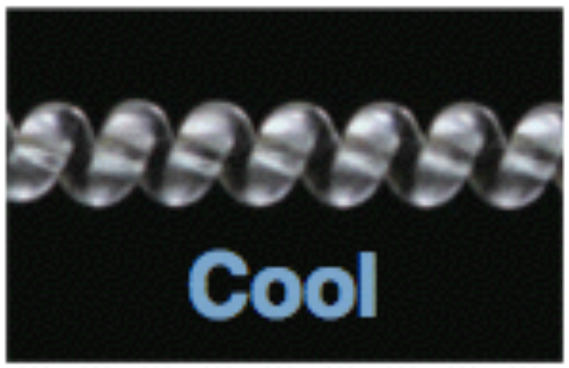
www.uni-stuttgart.de

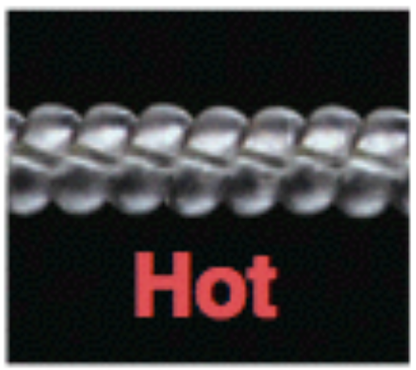
Artificial Muscles aus Angelschnüren

Haines et al. 2014









Kontraktion um 49%
Sehr große Kräfte (100fach biologischer Muskel)
5.3kW/kg (Leistungsdichte ähnlich einem Düsenantrieb)
Kaum Hysterese

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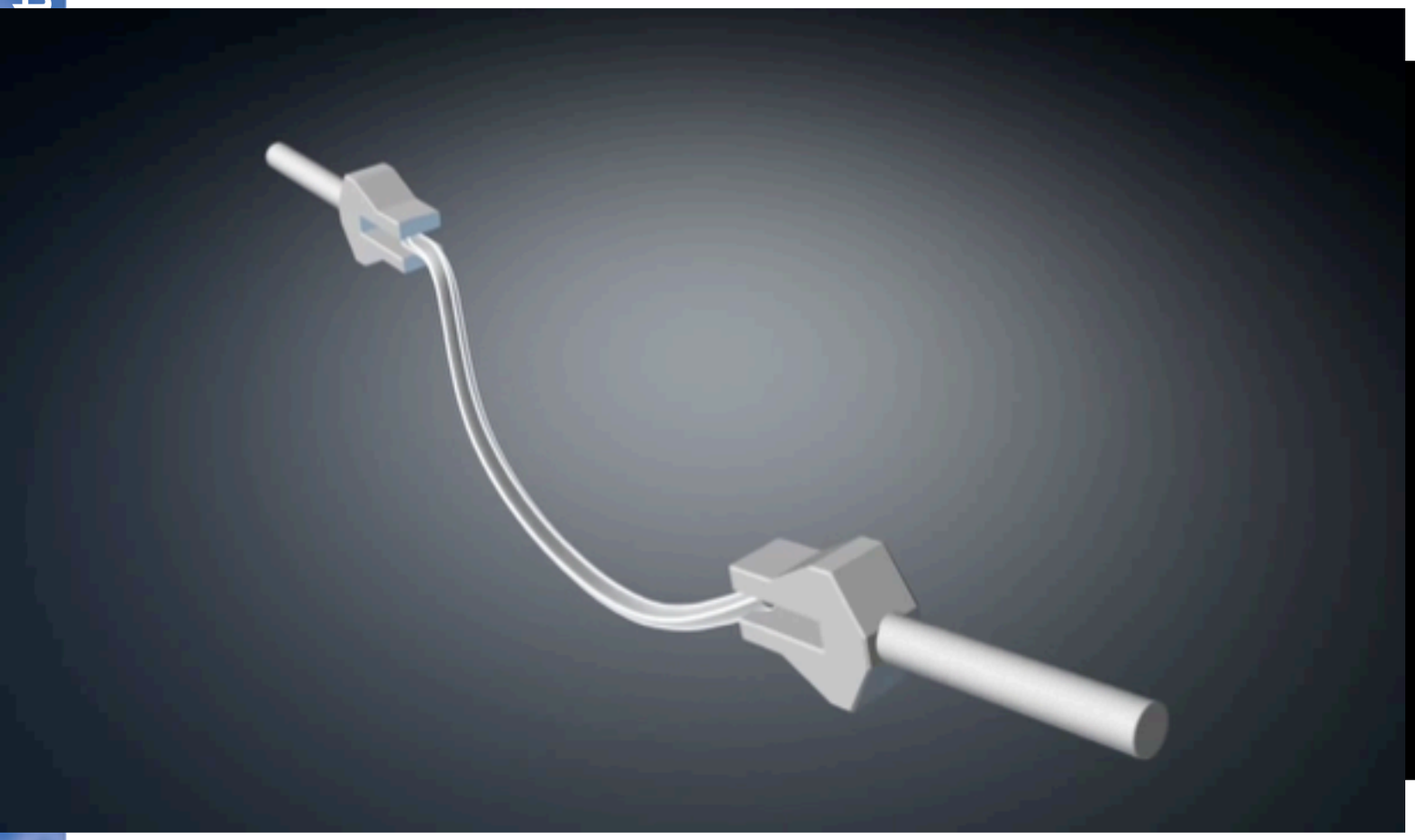
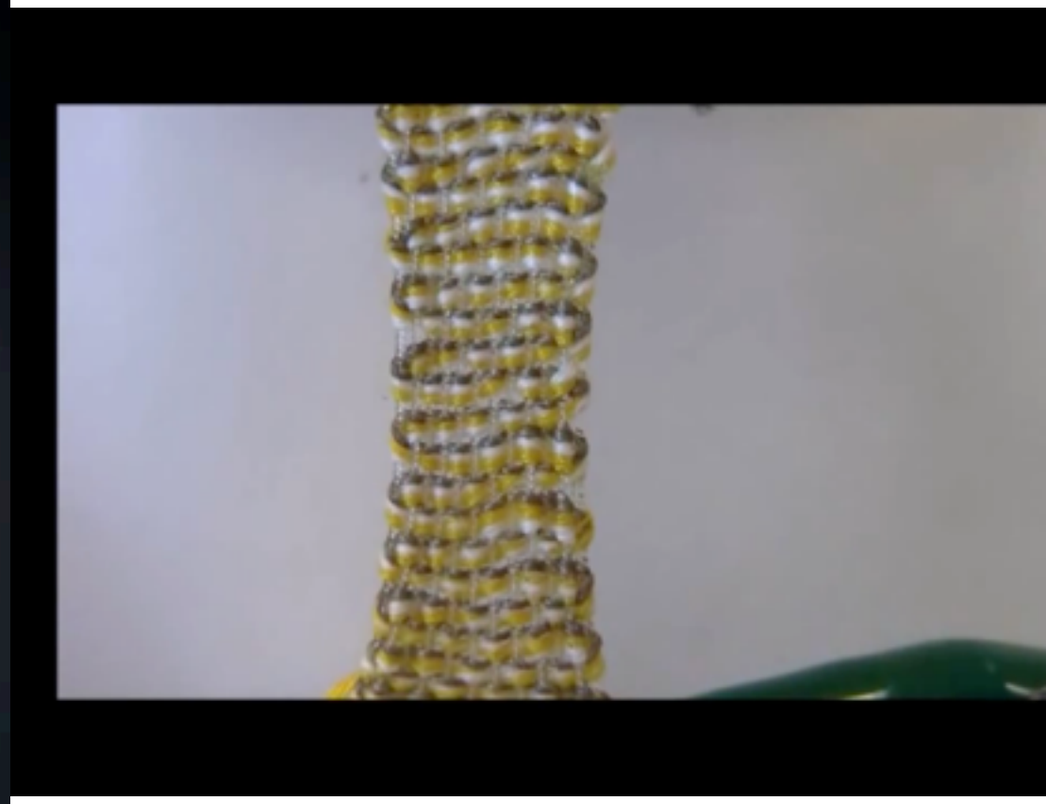
Artificial Muscles aus Angelschnüren

Haines et al. 2014





http://www.youtube.com/watch?v=Tba8Nf02OSI

http://www.youtube.com/watch?v=fNS0pxnQfdY

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Künstliche Muskeln

Actuator	Strain	Actuation Pressure	Density	Efficiency	Speed (fast AND slow)
Natural Muscle	●	●	●	●	●
Electromagnetic	●	●	○	●	○
Piezoelectric	○	●	◐	●	●
Shape Memory Alloy	◐	●	◐	○	○
Magnetostrictive	○	●	○	●	○
Electrostatic	●	○	●	●	●
Dielectric Elastomers	●	●	●	●	●
○ = Poor		◐ = Fair		● = Good	

Pelrine et al. 2002

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Zusammenfassung

1. Techn. Aktuatoren: E-Motor, Hydraulik, Pneumatik, sind sehr gut beschrieben, also existieren gute numerische Modelle die Kräfte und Bewegung vorhersagen.
2. Linear, also $F \propto u$ bzw. $M \propto u$
3. E-Motor mit Getriebe und Hydraulik sind „steife“ aktuatoren

-> das macht Regelung sehr einfach (z.B. PID).

4. Für Biorobotik gibt es andere Anforderungen
5. Elastizitäten speichern Energie und tolerieren Stöße/Kontakte
6. So viele „künstliche Muskeln“, warum gibt es keine Prothesen, warum gibt es kaum Anwendungen? „Künstlicher Muskel“ ist kein geschützter Begriff der definierte Kriterien erfüllen muss um adäquater Ersatz für biolog. Muskel zu sein.

Hausaufgaben

Der biologische Muskel: Videos zu Myology

Introduction http://www.youtube.com/watch?v=8rsk2Xzejnc
Structure http://www.youtube.com/watch?v=f_tZne9ON7c
Skeletal Muscle Sarcomere http://www.youtube.com/watch?v=MZJ6kTKDFmw
Skeletal Muscle Contraction http://www.youtube.com/watch?v=Vs0tZV35_pw