Lecture :
Industrial and Applied Robotics

REHAssist

The Linear Delta - Horizontal variant
- Belt transmission

The Linear Delta - Vertical variant
- Screw transmission

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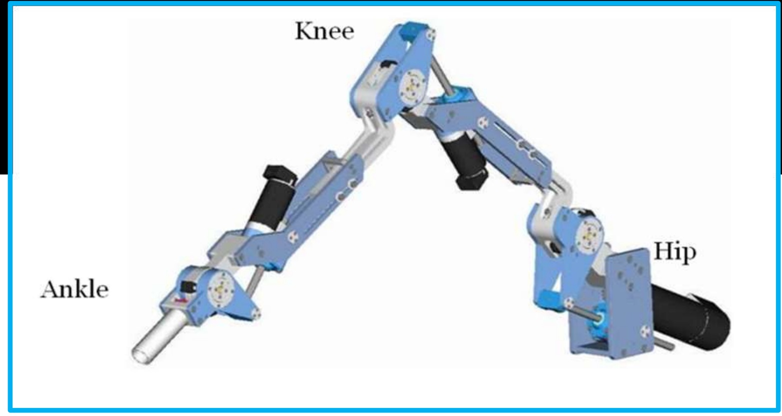
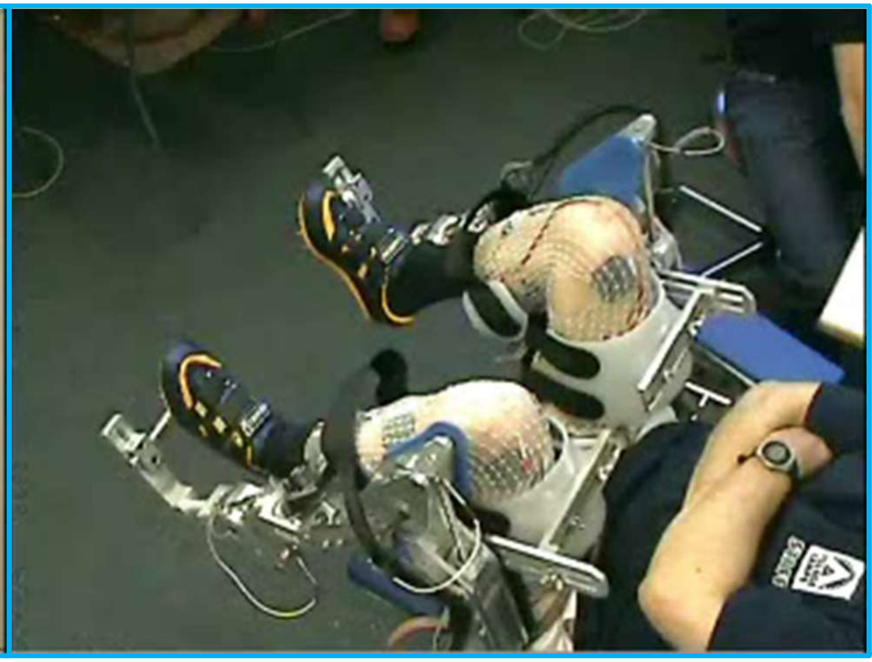
TRUMPF
TruLaser Cell 7040
TRUMPF
TruLaser Cell Series 7000
TruLaser 7040 in action

The Minangle –
Ref. Flexible Hinges realization

The Rehabilitation device MotionMaker
Screw-driven angular joint





Objectives of this robotics course

- Introduce/ recall the different mechanisms constituting an industrial robot,
- Evaluate and decide on evaluation methods for an industrial target application.
- Give basics to design and build a robot. Several design and application examples will be presented.
- Guest speakers from industry active in the field of robotics.

Industrial and Applied Robotics (MICRO 451)

1. Mechanisms
2. Applications
3. Guest Talks
4. Project

EPFL

Agenda 2025

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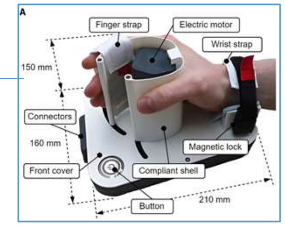
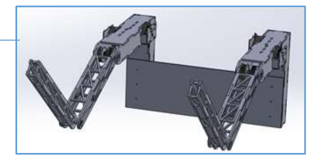
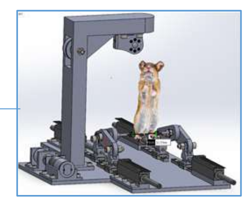
Week	day	content		
1	19.2.2025	Course introduction, organization and objectives	Mechanisms and components - I- Springs and elasticty	
2	26.2.2025	Mechanisms and components - II- Trajectry, eigenfrequency and precision		Project distribution Forming groups
3	5.3.2025	Introduction to Finite Elements - Vibration assessment of a Swiss turning machine. (Prof M. Thurneyse - HEPIA)	Session 1- Robotics project	
4	12.3.2025	Mechanisms and components - III.1- transmissions + Use case implementation		Robotics project
5	19.3.2025	Mechanisms and components - III.2- transmissions + Use case implementation		Robotics project
6	26.3.2025	Mechanisms and components - IV- Guides		Robotics project
7	2.4.2025	Actuation and transmission in industrial applications Max Erik (Maxon)	Robotics project	
8	9.4.2025	Cobotics : Collaborative robotics	Mid term - presentations	
9	16.4.2025	Robotics project		
	23.4.2025	Holidays		
10	30.4.2025	Microassembly : concepts, requirements, and techniques		
11	7.5.2025	Mechanisms and solutions for mdeical rehabilitation		Robotics project
12	14.5.2025	Robotics project		
13	21.5.2025	Robotics project		
15	28.5.2025	Robotics project - <u>Final oral presentations</u>		

Projects	Skills	Nb. Person
Ankle exoskeleton	CAD	**5**
Hand rehabilitation device	CAD	**5**
Delta with linear actuator	CAD, Simulation	**6**
Mobile platform	CAD	**6**
Dual platform Isochronic	CAD, Simulation	**6**
Supernumerary Robot	CAD	**6**
Design of a linear axis with ball screw	CAD, hand on experience	**4**
Design of a linear axis with rack and pinion	CAD, hand on experience	**3**
Design of a linear axis with belts	CAD, hand on experience	**3**
Comparative studies, simulation of exoskeleton for lower limb	Simulation, Control	**3**
Revisit a lambda robot for mice gait assessment	CAD	**7**
Endoskeleton	Innovation - mechanisms	**3**
Free project		







Organization of the course - grades

Project	30%
Final exam	70%

1)Springs and elastic effect

1) Springs and their different applications

2) How the elastic effect of a robotic arm affects its positioning precision?

Dynamic behavior of a robotic arm: Rigid body versus Elastic body (trajectory, materials, and precision)

- Simple single-arm case
- Multi-axes case

3) “Quality factor” and precision.

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2) Materials

1) Rules of similitude. Lorel and Hardy.

2) Materials, eigenfrequencies, and applications

3) Couplings (accouplement)

1) Rigid and flexible couplings

2) Shaft couplings (rotation-rotation)

3) Linear couplings

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4) Transmissions

1) Direct drives

2) Kinematic transmissions

3) Gears and planetary gearboxes

4) Harmonic drives

5) Toothed belts

6) Rack pinions, screws, ball screws, ….

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5) Guides (Rotational, linear)

1) Rotation guides (ball bearings <u>and</u> dry bearings)
2) Linear guides (recirculated balls, rollers, bushings, and roller bushings, ….)

1)Springs and elastic effect

1) Springs and their different applications

2) How the elastic effect of a robotic arm affects its positioning precision?

Dynamic behavior of a robotic arm: Rigid body versus Elastic body (trajectory, materials, and precision)

- Simple single-arm case
- Multi-axes case

3) "Quality factor" and precision.

Open discussion …

Why and in which cases do we use «Springs» or the effect of «elasticity»?

- Static behavior….. examples
- Dynamic behaviour….. examples

Springs to overconstrain mechanisms and reduce the backlash in reductors and screw-nut transmissions

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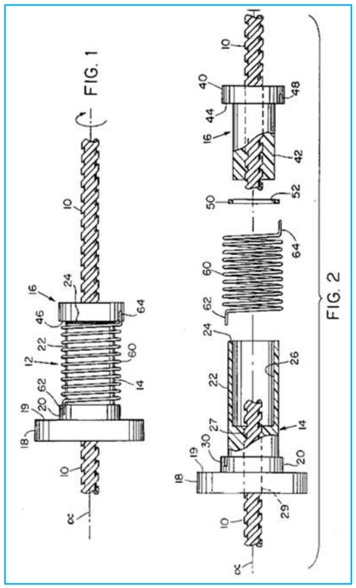
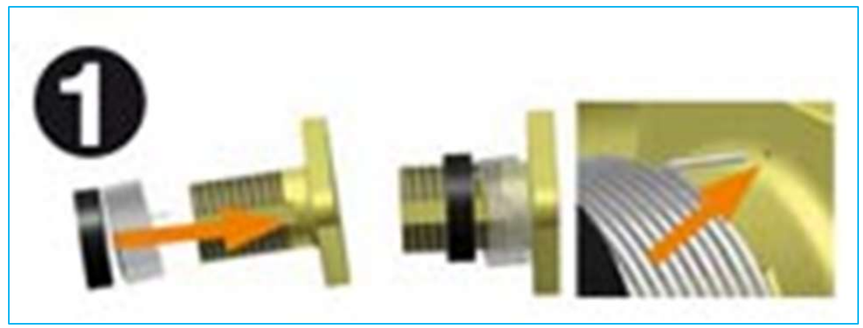
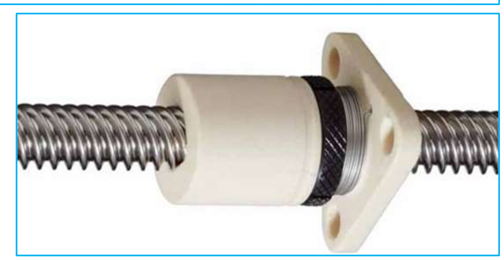
How to reduce backlash in screw-nut transmissions?







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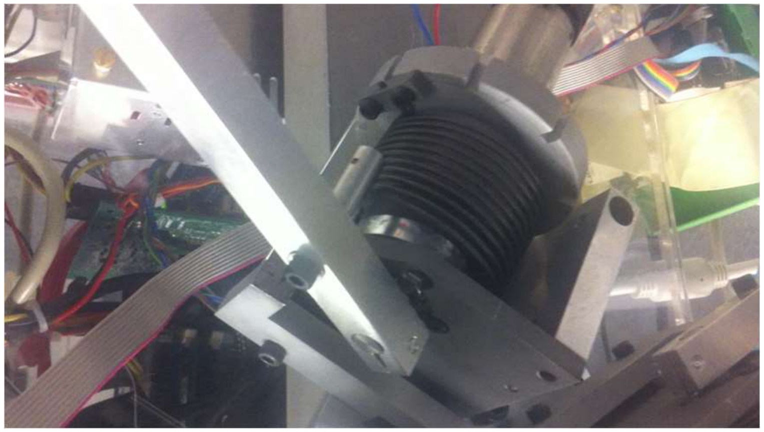
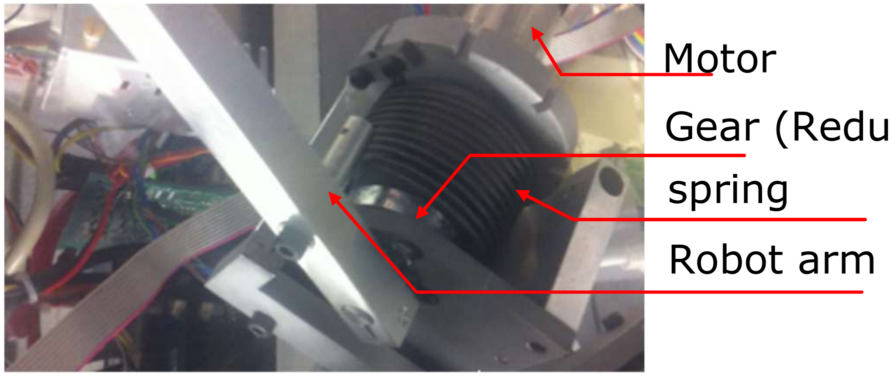
How to reduce gearbox backlash ?

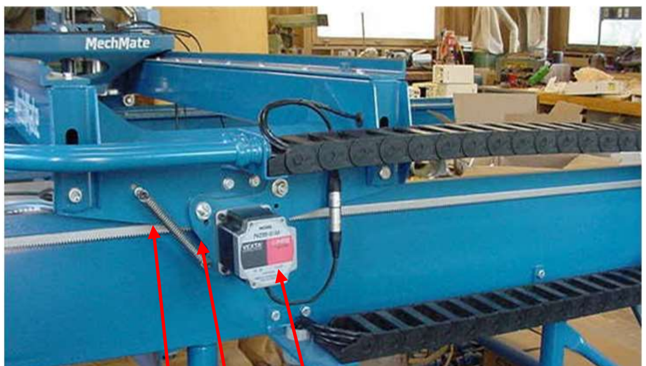


The spring makes it possible to push the robot arm always towards a defined direction and the play is thus compensated. This avoids positioning at +/- the backlash.



Springs to overconstrain mechanisms and reduce the backlash in reductors and screw-nut transmissions

Backlash reduction in rack-pinion transmissions



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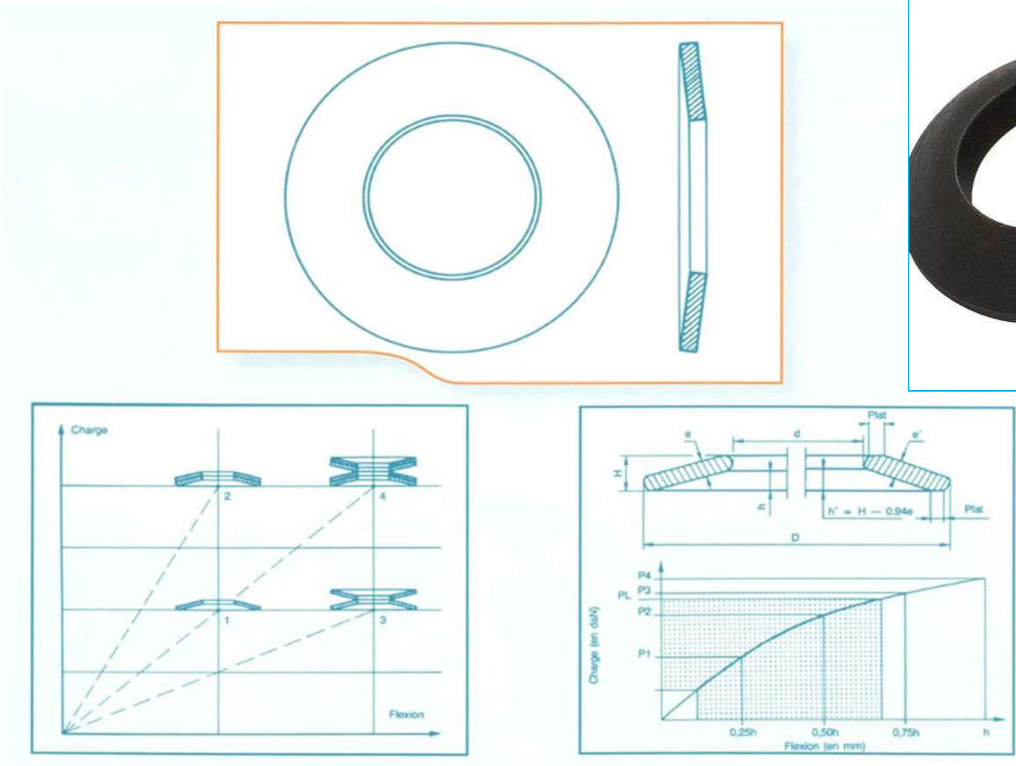
Bearing's overconstraint

Elastic washers
(rondelles élastiques)



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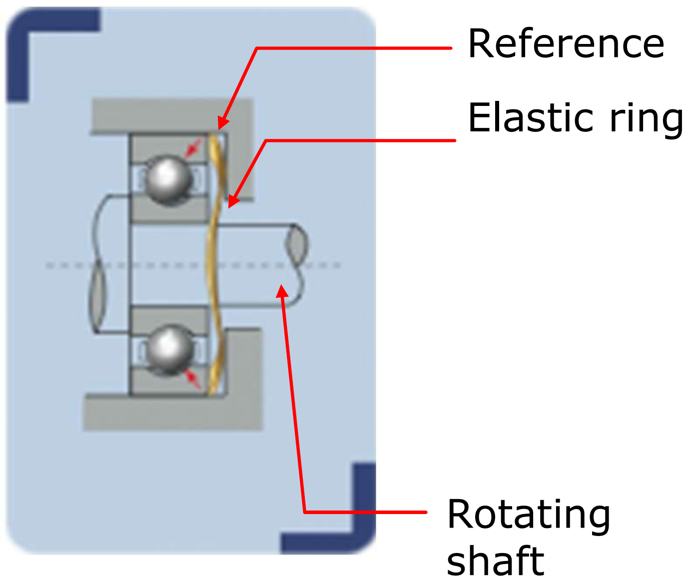
Elastic washer



[Ref KUBO-TECH rondelles Belleville]

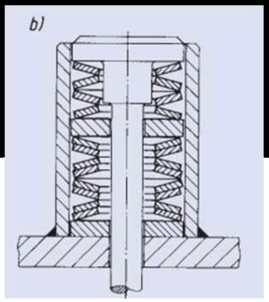
Ring springs have a conical annular shape and can be subjected to **static or permanent axial loads**.

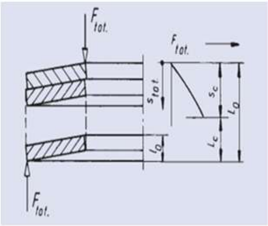
Obtaining characteristic curves and predefined deflections is achieved by combining the individual springs to form packages or columns.

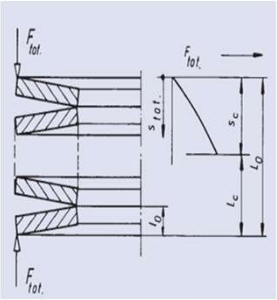
When the individual springs are stacked in the same direction, the elastic force is proportional to the number of individual springs for the same deflexion.

When the individual springs are stacked in opposite directions, the deflexion is proportional to the number of individual springs for the same elastic force.

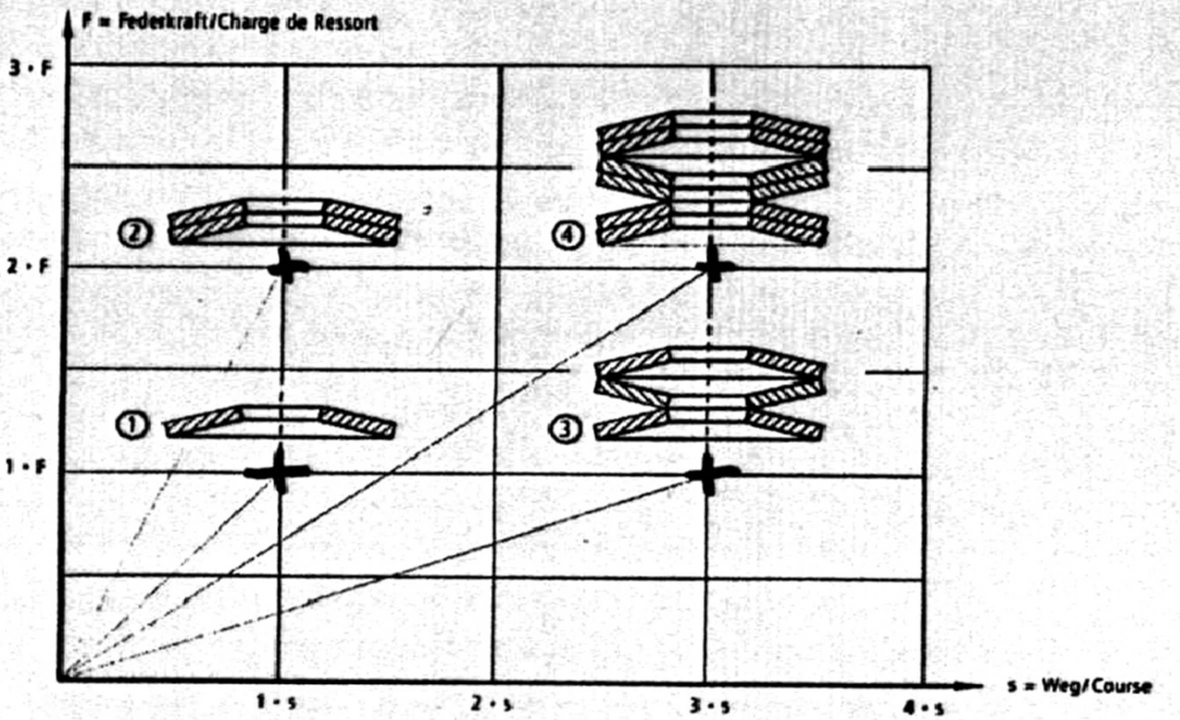
Ring springs are usually used when a strong force is required with a reduced deflexion. Thanks to the pressure and the length, the spring can be used almost everywhere







Kombination von Einzelfedern | **Combinaison de ressorts individuels**



① **Einzelteller / Ressort individuel**

F_{ges} = F

S_{ges} = S

② **Federpaket aus Einzeltellern/**
Paquet de ressorts composé de ressorts individuels

F_{ges} = $n \cdot F$ = $2 \cdot F$

S_{ges} = S

③ **Federsäule aus Einzeltellern/**
Colonne de ressorts composé de ressorts individuels

F_{ges} = F

S_{ges} = $i \cdot s$ = $3 \cdot s$

④ **Federsäule aus Federnpaketen/**
Colonne de ressorts composé de paquets de ressorts

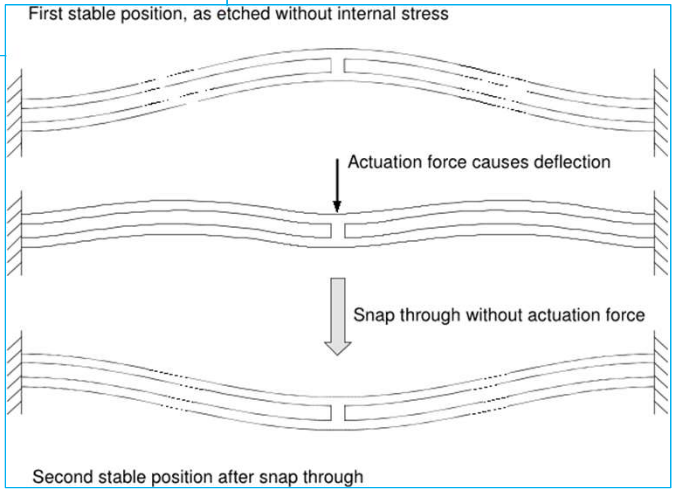
F_{ges} = $n \cdot F$ = $2 \cdot F$

S_{ges} = $i \cdot s$ = $3 \cdot F$

2-positions over constrained rings : Bi-stable rings

Washers with two static equilibrium positions.

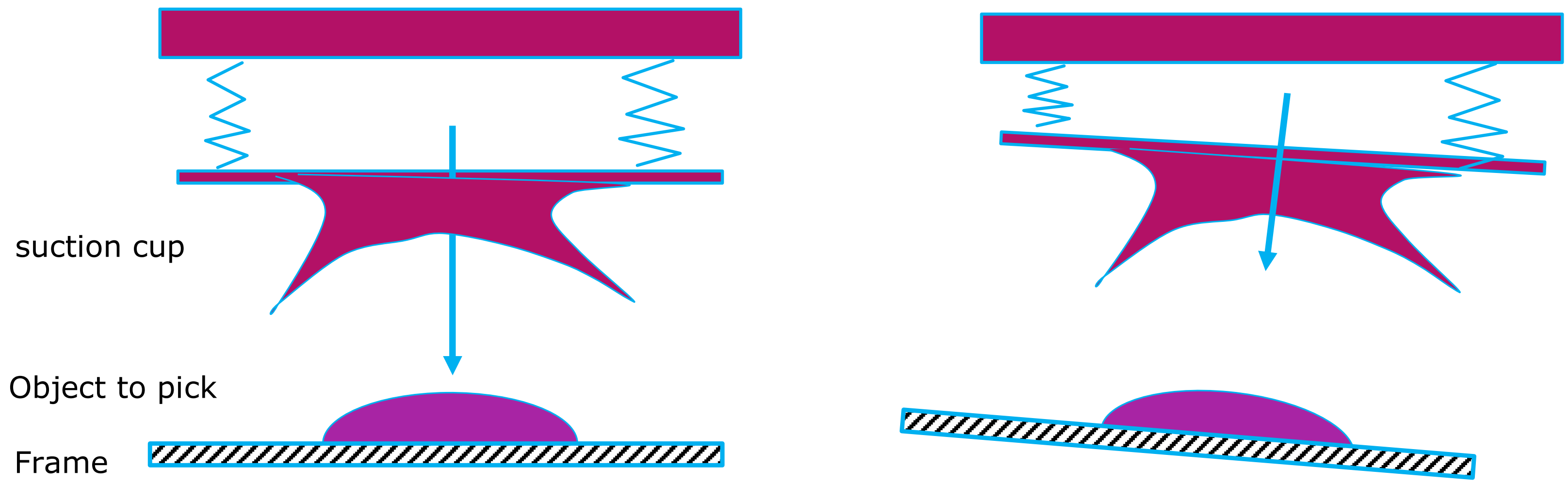
Allows to constraint elements between them at defined positions. Hence, avoiding the use of a clamping element.



Correction of alignment

1- Compliant elements

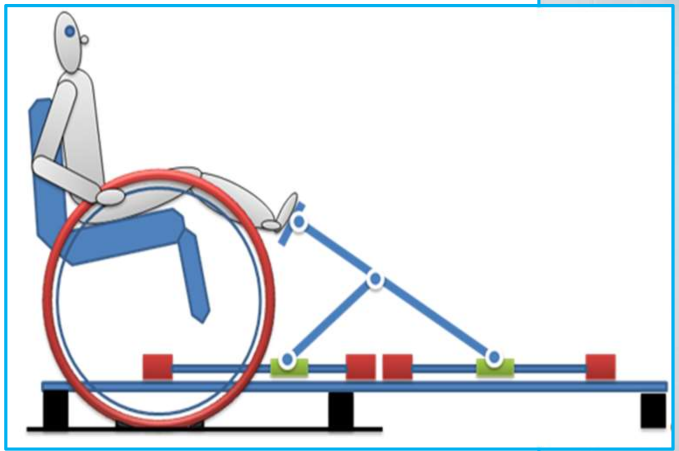
Springs mounted with **a grasping device**, RCC mechanism,…)



2- Coupling bellows for alignment correction

Springs to compensate the effect of gravity:

Example of the robot «Lambda»



Springs to compensate the effect of gravity:

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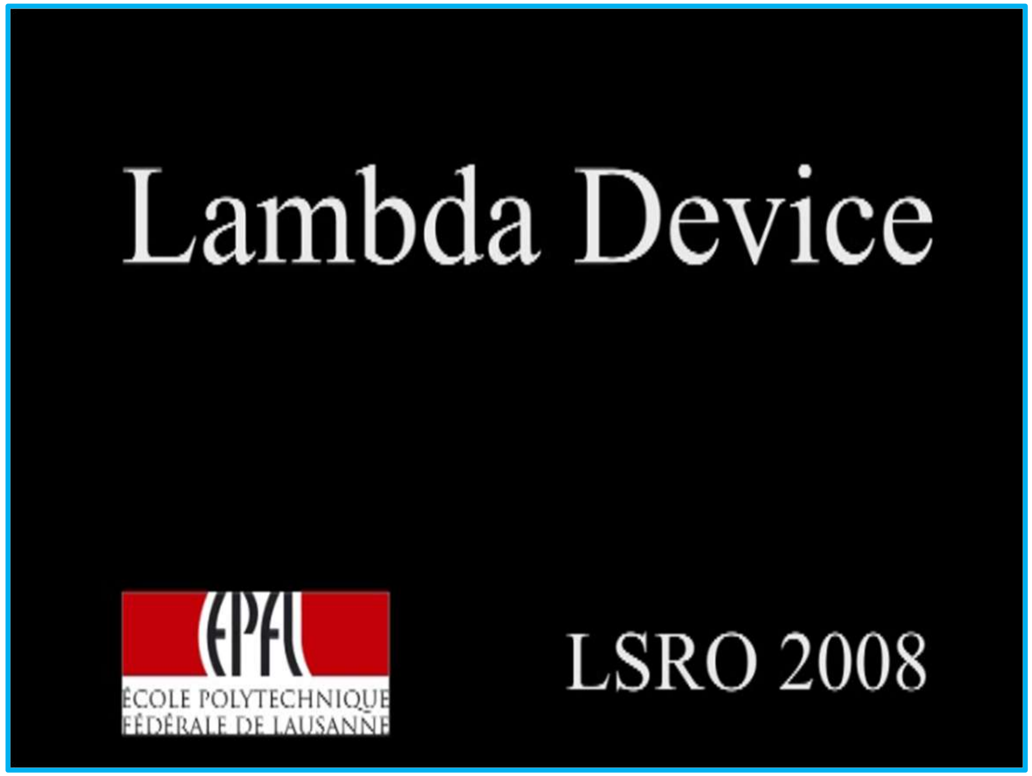
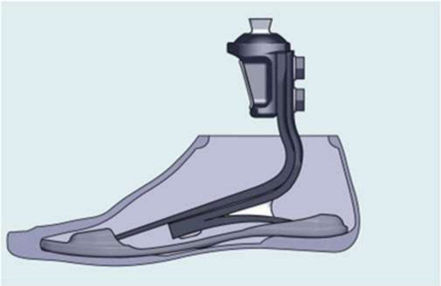
Example of the robot «Lambda»

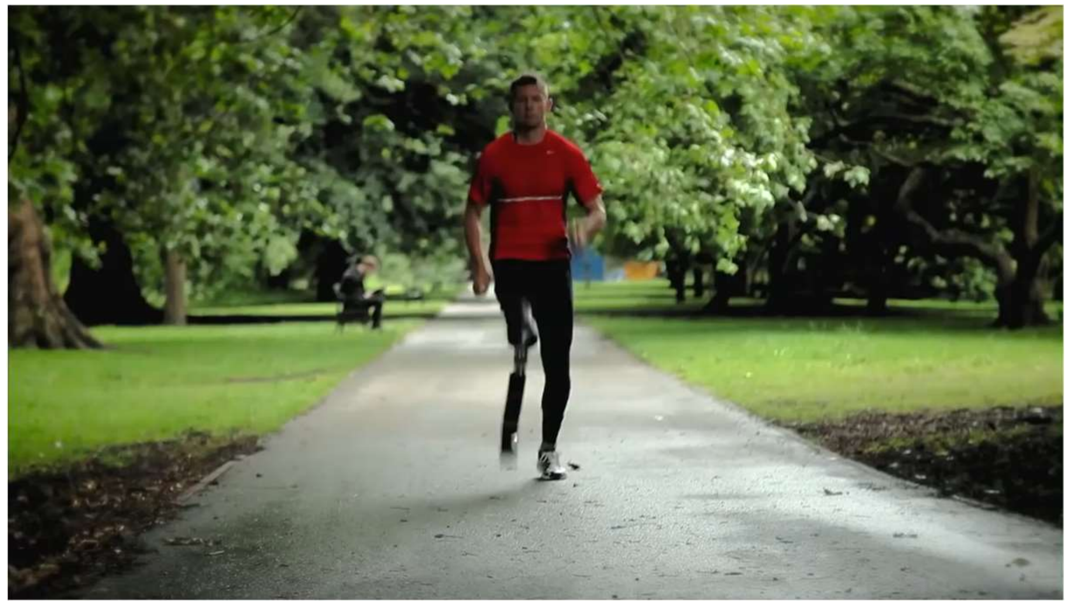


Springs to store energy



[Ref. Otto Bock]
Energy storage. A foot made with carbon fiber for energy storage literally gives you a spring in your step. **The carbon fiber acts as a spring**, compressing as you apply weight and **propelling you forward as your foot rolls**, returning energy to your step as the spring releases. Some prostheses have one spring in the heel and a second spring in the forefoot: just what you need for walking at various speeds, running, climbing hills or descending stairs with a secure, confident stride. With carbon fiber, the longer the spring, the more energy it can store and the more responsive the foot will be.

And what else ?



And what else ?

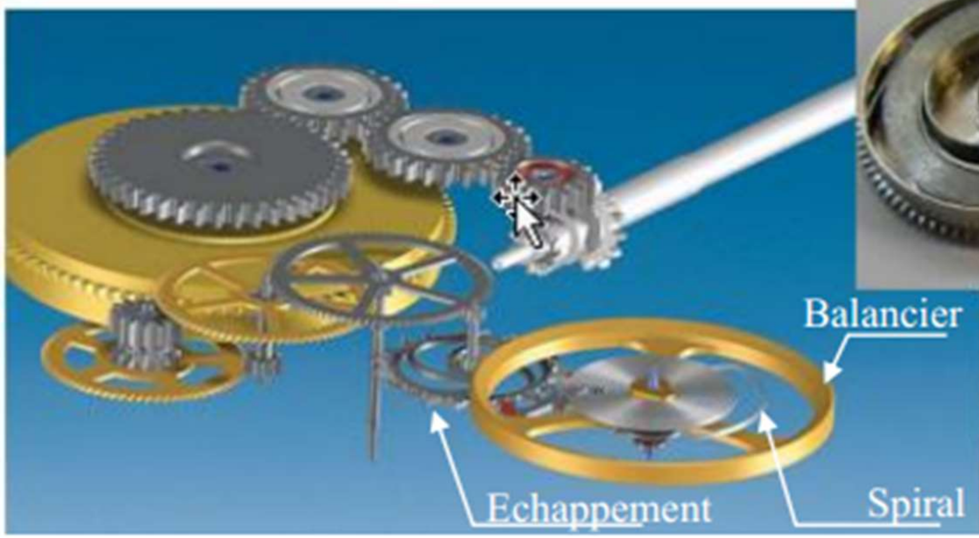
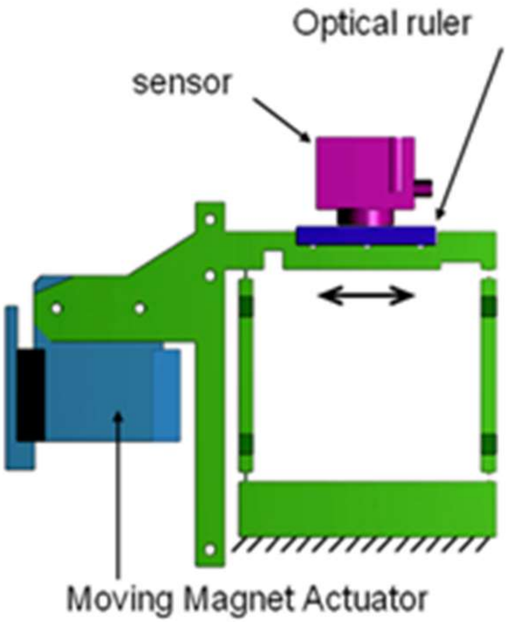


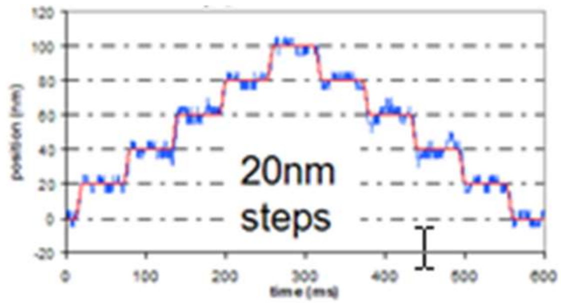
Fig. Ci-dessus, «Barillet » ouvert et ressort à barillet

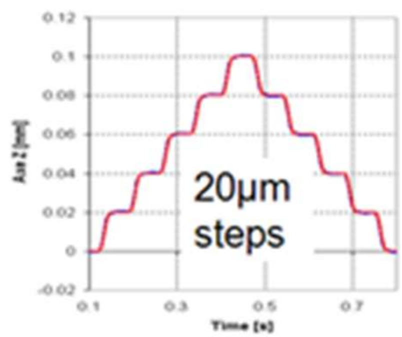
Fig. Ressort de barillet (à gauche) qui fournit l'energie stockée – L'oscillateur (balancier, spiral et l'écahappement) règle le débit.

Cylinder spring (left) that provides stored energy to the oscillator

And what else ?







In this case, the modeling of these guides corresponds exactly to a spring-mass mechanism