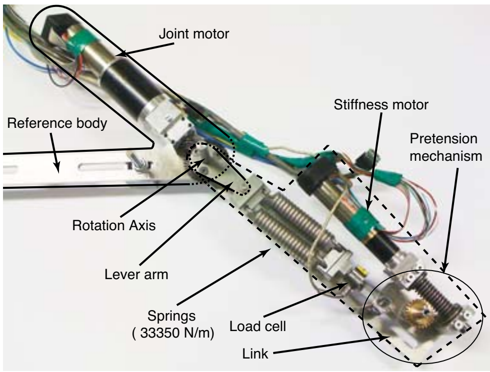
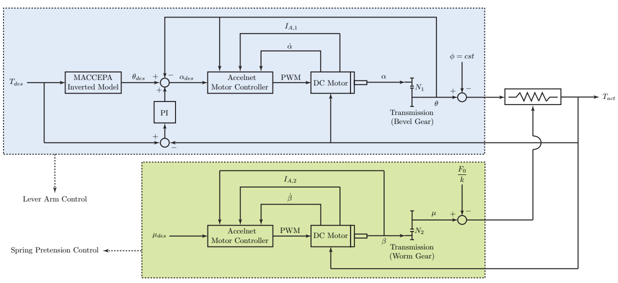
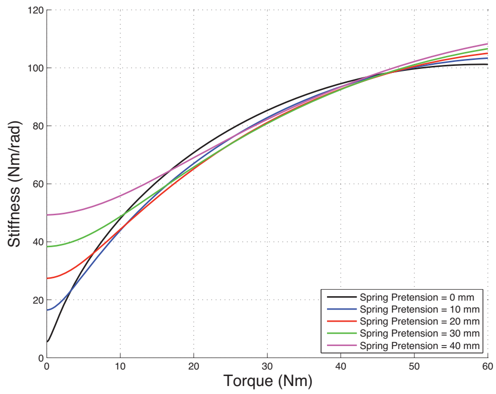
MACCEPA

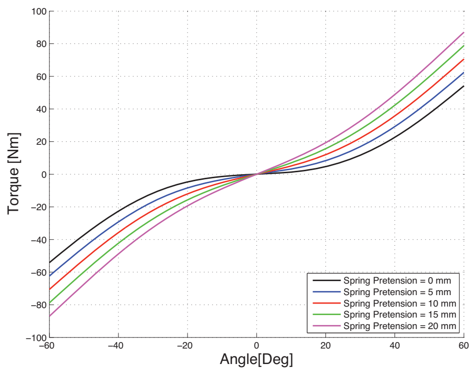
Mechanically Adjustable and Controllable Compliance Equilibrium Position Actuator



Operating Data				
#	(quantity)		(unit)	(value)
Mechanical				
1	Continuous Output Power		[W]	320
2	Weight		[Kg]	2,4
3	Nominal Torque		[Nm]	50
4	Nominal Speed		[rad/s]	5,8
5	Nominal Stiffness Range	Maximum	[Nm/rad]	110
6		Minimum	[Nm/rad]	5
7	Nominal Stiffness Variation Time		[s]	2,6
8	Peak Torque		[Nm]	70
9	Maximum Speed		[rad/s]	5,8
10	Maximum Stiffness		[Nm/rad]	110
11	Minimum Stiffness		[Nm/rad]	5
12	Maximum Elastic Energy		[J]	27,9
13	Maximum Torque Hysteresis		[%]	3,6
14	Maximum Deflection		[°]	60
15	Minimum Deflection		[°]	0
16	Rotation Angle		[°]	150
17	Angular Resolution		[°]	
Electrical				
18	Nominal Voltage		[V]	48
19	Nominal Current		[A]	12
20	Maximum Current		[A]	36
Control				
21	Voltage Supply		[V]	24
22	Nominal Current		[A]	2
23	I/O Protocol		[]	EtherCat

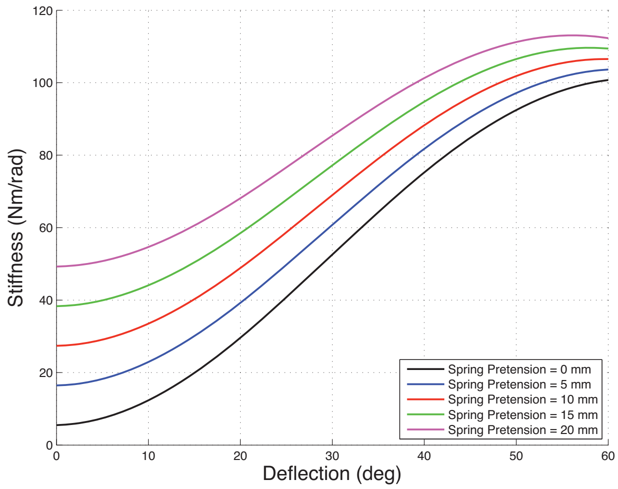






MACCEPA

Additional Characteristics



Additional sensors data			
#	(quantity)	(unit)	(value)
a0	Sensor a: Encoder 1		
a1	Resolution	[deg]	0,045
a2	Range	[deg]	360
a3	I/O Protocol	Incremental quadrature encoder	
a4			
a0	Sensor a: Encoder 2		
a1	Resolution	[deg]	0,045
a2	Range	[deg]	360
a3	I/O Protocol	Incremental quadrature encoder	
a4			
c0	Sensor c: Load Cell		
c1	Resolution		16 Bit
c2	Range	[Kg]	227
c3	I/O Protocol	ADC (Analog to Digital)	
c4			

The feedback system consist of high resolution incremental encoders, force and current sensors.

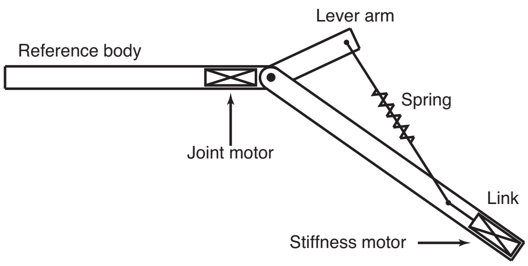
The device is driven by TwinCat real time operating system which can control the actuator within loops less than one millisecond. The complexity of hardware design, amount of input/output ports is implying use of a fast data transfer bus. To obtain high speed data transfer rate we use relatively new industrial Ethernet standard (EtherCat) that can offer us a remote control as well.

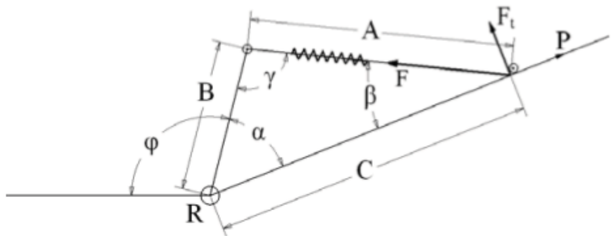
Real time algorithms will be managed by high level and low level controllers. The low level control is done by integrated Accelnet drives, able to communicate by EtherCat within real time system and provide sufficient power to achieve required high torques.

For high level control of the actuator a visual user interface is built using Visual C# environment.

MACCEPA

Model





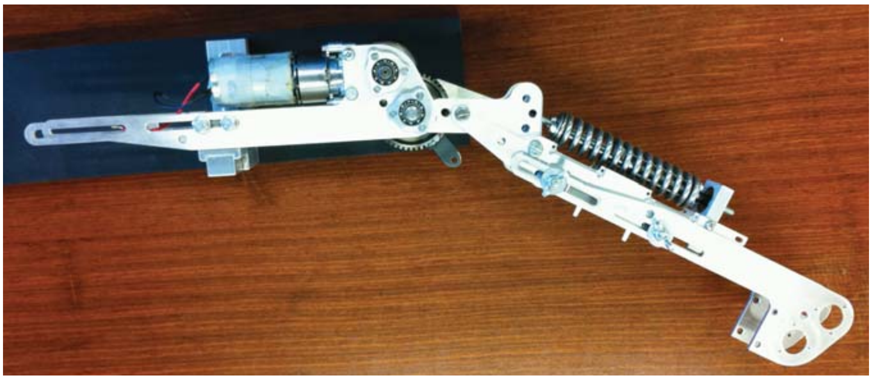
a = Rotation point
b = Fixed point on right body. The cable between the spring and the pre-tension mechanism is guided around this point
c = Fixed point on lever arm, where the spring is attache
F = Force due to extension of the spring
Ft = Component of F orthogonal to line ab, that generates torque
k = Spring constant, assuming linear spring
B = Length lever arm, which sets equilibrium position
C = Distance between point a (rotation point) and point b on the right body
P = Extension of the spring caused by pre-tensioning
α = φ-θ , Angle between lever arm and right body
φ = Angle between extension of left body and lever arm, equiibrium position
θ = Angle between extension of left body and output link.

Mathematical Model

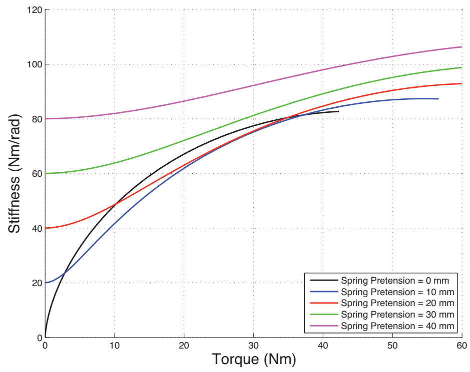
101	Equilibrium Point Function	$x_e = \phi$
102	Energy Function	$H = \frac{1}{2}k(\sqrt{B^2+C^2-2BC\cos\alpha} - \lvert C-B\rvert + P)^2$
103	Output Torque Function	$\tau = kBC\sin\alpha(1 + \frac{P-\lvert C-B\rvert}{\sqrt{B^2+C^2-2BC\cos\alpha}})$
104	Output Stiffness Function	$\sigma = kBC\cos\alpha(1 + \frac{P-\lvert C-B\rvert}{\sqrt{B^2+C^2-2BC\cos\alpha}}) - \frac{kB^2C^2\sin\alpha^2(P-\lvert C-B\rvert)}{(B^2+C^2-2BC\cos\alpha)^{3/2}}$
105	Spring Force Function	$F = k(\sqrt{B^2+C^2-2BC\cos\alpha} - \lvert C-B\rvert + P)$
106	Springs to Motors Transmission Ratio	$A_1 = \frac{d\Delta l}{d\phi} = \frac{BC\sin(\phi-\theta)}{\sqrt{B^2+C^2-2BC\cos(\phi-\theta)}}$ $A_2 = \frac{d\Delta l}{d\theta} = 1$
107	Springs to Output Transmission Ratio	$B = \frac{d\Delta l}{d\theta} = \frac{-BC\sin(\phi-\theta)}{\sqrt{B^2+C^2-2BC\cos(\phi-\theta)}}$

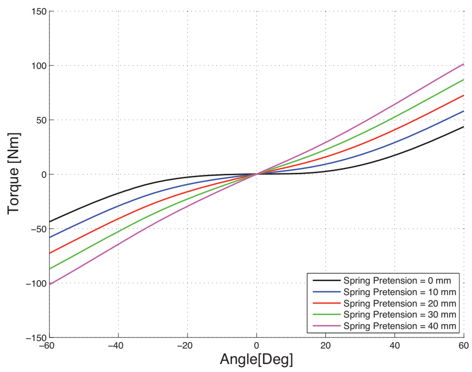
MACCEPA

Mechanically Adjustable and Controllable Compliance Equilibrium Position Actuator (under construction)



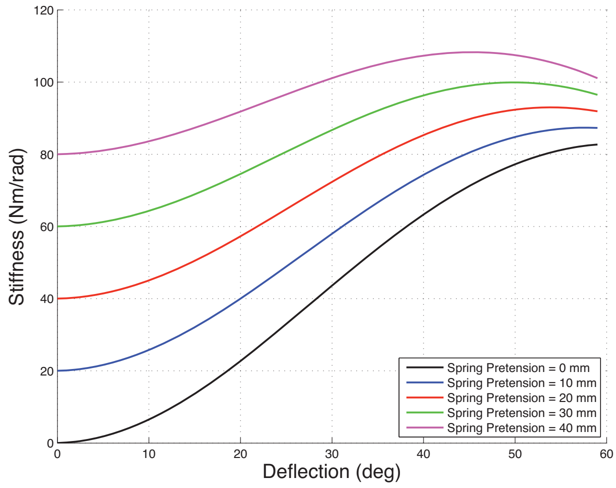
#	(quantity)		(unit)	(value)
Operating Data				
Mechanical				
1	Continuous Output Power		[W]	
2	Weight		[Kg]	
3	Nominal Torque		[Nm]	
4	Nominal Speed		[rad/s]	
5	Nominal Stiffness Range	Maximum	[Nm/rad]	
6		Minimum	[Nm/rad]	
7	Nominal Stiffness Variation Time		[s]	
8	Peak Torque		[Nm]	
9	Maximum Speed		[rad/s]	
10	Maximum Stiffness		[Nm/rad]	
11	Minimum Stiffness		[Nm/rad]	
12	Maximum Elastic Energy		[J]	
13	Maximum Torque Hysteresis		[%]	
14	Maximum Deflection		[°]	
15	Minimum Deflection		[°]	
16	Rotation Angle		[°]	
17	Angular Resolution		[°]	
Electrical				
18	Nominal Voltage		[V]	
19	Nominal Current		[A]	
20	Maximum Current		[A]	
Control				
21	Voltage Supply		[V]	
22	Nominal Current		[A]	
23	I/O Protocol		[]	





MACCEPA

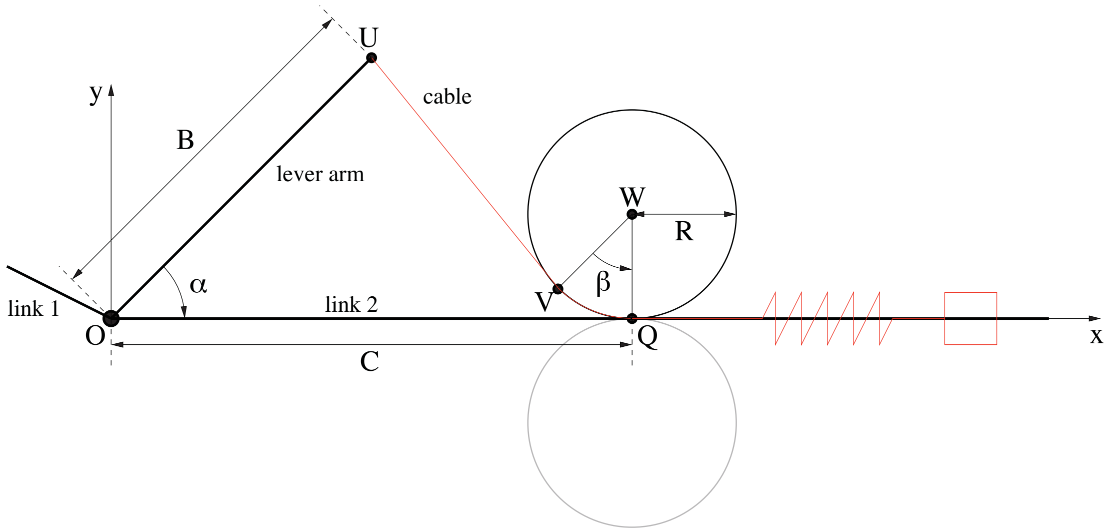
Additional Characteristics



Additional sensors data			
#	(quantity)	(unit)	(value)
a0	Sensor a: Encoder 1		
a1	Resolution	[deg]	
a2	Range	[deg]	
a3	I/O Protocol		
a4			
a0	Sensor a: Encoder 2		
a1	Resolution	[deg]	
a2	Range	[deg]	
a3	I/O Protocol		
a4			
c0	Sensor c: Load Cell		
c1	Resolution		
c2	Range	[Kg]	
c3	I/O Protocol		
c4			

MACCEPA

Model



Mathematical Model

101	Equilibrium Point Function	
102	Energy Function	
103	Output Torque Function	
104	Output Stiffness Function	
105	Spring Force Function	
106	Springs to Motors Transmission Ratio	
107	Springs to Output Transmission Ratio	