

# Variable Stiffness Actuators: the user's point of view.

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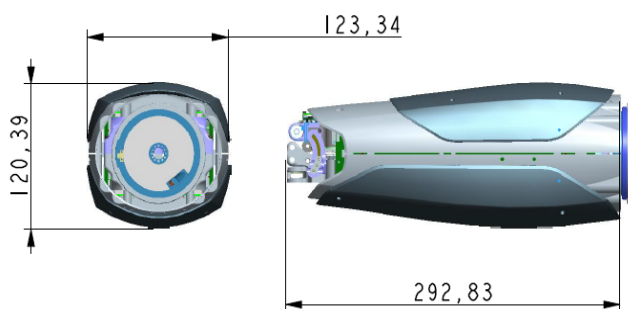
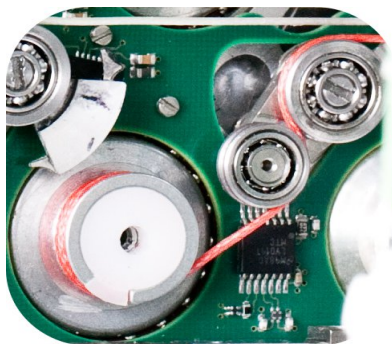
“FAS A flexible Antagonistic spring element  
datasheet”

Multimedia Extension #2

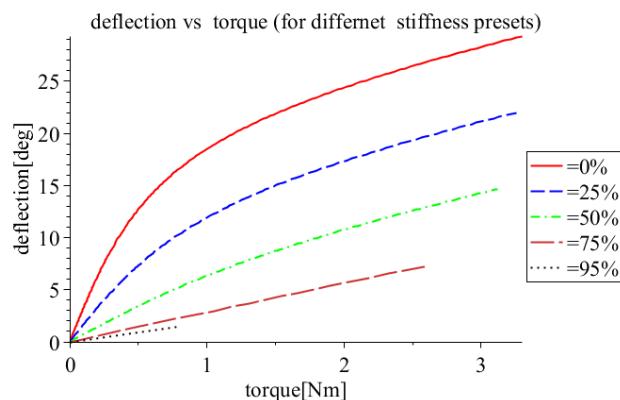
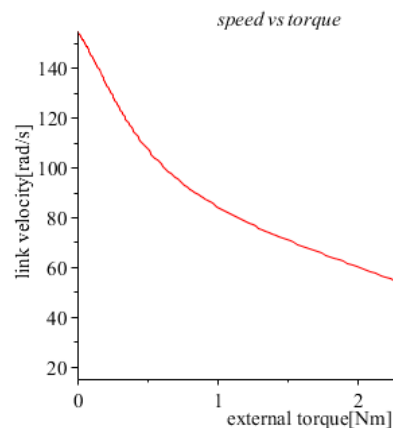
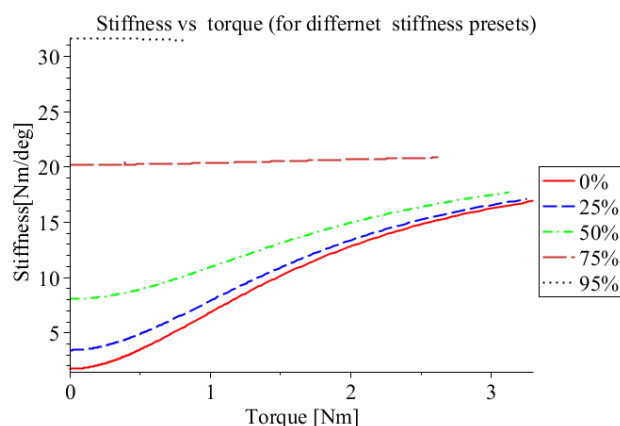
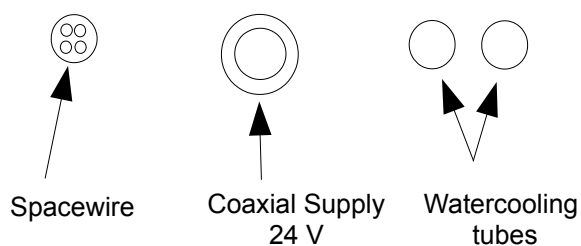
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# FAS A flexible Antagonistic spring element

## Antagonistic finger joint

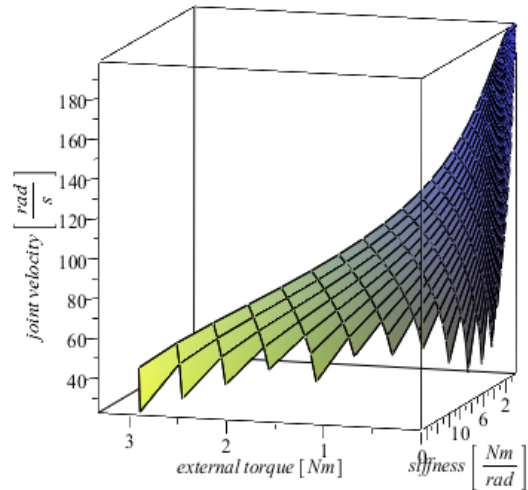
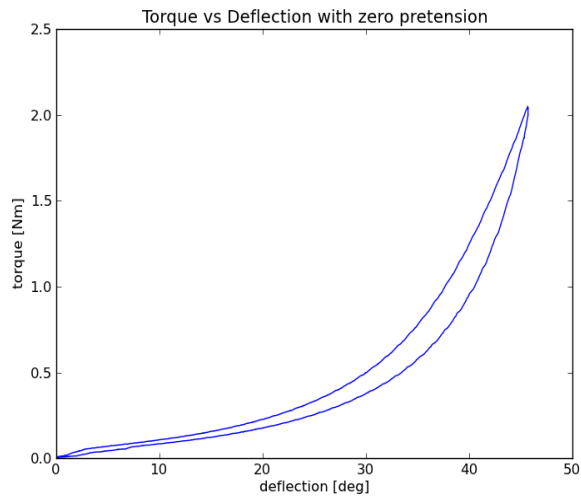


Operating Data			
#	(quantity)	(unit)	(value)
Mechanical			
1	Continuous Output Power	[W]	67,2
2	Nominal Torque	[Nm]	2,2
3	Nominal Speed	[rad/s]	16,74
4	Nominal Stiffness Variation Time	with no load	[ms] 29
5		with nominal torque	[ms] 29
6	Peak (Maximum) Torque	[Nm]	4,9
7	Maximum Speed	[rad/s]	152
8	Maximum Stiffness	[Nm/rad]	36
9	Minimum Stiffness	[Nm/rad]	1,8
10	Maximum Elastic Energy	[J]	0,22
11	Maximum Torque Hysteresis	[%]	20
12	Maximum deflection	with max. stiffness	[°] 1,5
13		with min. stiffness	[°] 30
14	Active Rotation Angle	[°]	150
15	Angular Resolution	[°]	3,1
16	Weight	[Kg]	3,9
Electrical			
17	Nominal Voltage	[V]	24
18	Nominal Current	[A]	3
19	Maximum Current	[A]	7
Control			
20	Voltage Supply	[V]	24
21	Nominal Current	[A]	0,1
22	I/O protocol	[]	Biss

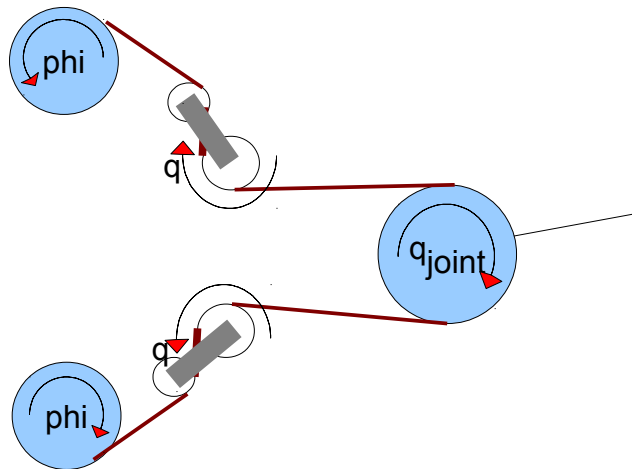


# Actuator Name (repetition)

## Additional Characteristics



Additional sensors data			
#	(quantity)	(unit)	(value)
a0	Sensor phi		
a1	Resolution	[Bit]	12
a2	Range	[deg]	360
a3	I/O protocol		Biss C
ax	(specific sensor properties)	[]	relative
b0	Sensor q		
b1	Resolution	[Bit]	12
b2	Range	[deg]	45
b3	I/O protocol	[]	Biss C
b4	(specific sensor properties)		absolut



All curves and parameters fit to the metacarpal joint of the index finger. The FAS can adapt to different tendon length and stiffness curve by changing the fix point of the spring and the spring constant.

In the forearm of the DLR Handarm System are 19 FAS actuators and 2 BAVS (bidirectional antagonistic variable stiffness actuators) located. To dissipated the power loss of the motors and electronics the forearm has a structural embedded water cooling.

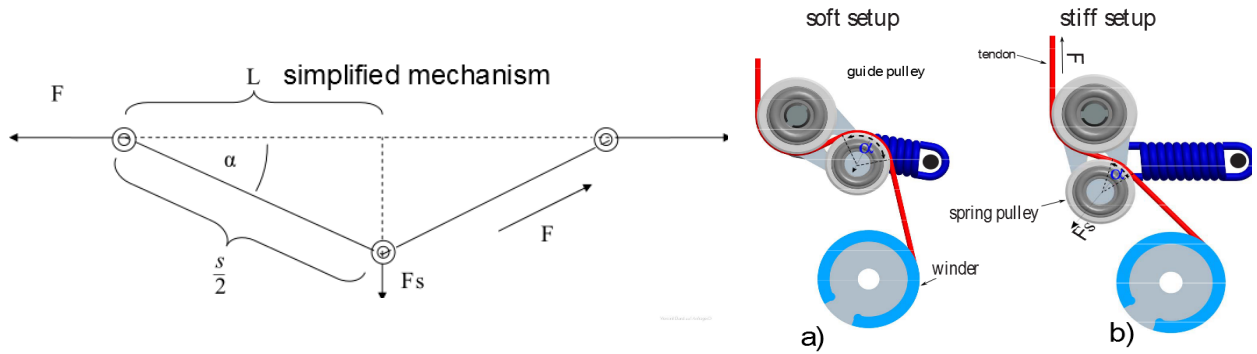
Also an embedded supply layer is integrated to power the motors and to safe connectors.

The velocity vs torque curve shows the snipping speed of the finger. The finger is elongated in the PIP and DIP joint.

All formulas fit to the simplified model because the formulas of the real system are to complicated and need to much space.

# Actuator Name (repetition)

## Model



## Mathematical model

101	Recoil Point Function	$q_{joint} = \frac{\varphi_1 - \varphi_2}{2}; \sigma = \frac{\varphi_1 + \varphi_2}{2}$
102	Energy Function	$H(\sigma, q_{joint}) = \frac{c}{2} \cdot (sw - L \cdot \sqrt{(1 - 4L^2(s\theta - (q_{joint} + \sigma)r)^2)})^2 - (sw - L \cdot \sqrt{(1 - \frac{4L^2}{(s\theta - (-q_{joint} + \sigma)r)^2})})^2$
103	Output Torque Function	$\tau(q_{joint}, \sigma) = \frac{-(0.5 \cdot c \cdot (sw \cdot L \cdot \sqrt{(1 - \frac{(4 \cdot L^2)}{(s\theta - (q_{joint} + \sigma) \cdot r)^2})}) \cdot r) \cdot (0.5 \cdot c \cdot (sw \cdot L \cdot \sqrt{(1 - \frac{(4 \cdot L^2)}{(s\theta - (-q_{joint} + \sigma) \cdot r)^2})}) \cdot r)}{\sqrt{(1 - \frac{(4 \cdot L^2)}{(s\theta - (q_{joint} + \sigma) \cdot r)^2})} + \sqrt{(1 - \frac{(4 \cdot L^2)}{(s\theta - (-q_{joint} + \sigma) \cdot r)^2})}}$
104	Output Stiffness Function	$k(q_{joint}, \sigma) = \frac{d\tau}{dq_{joint}, \sigma}$
106	Springs to Motors Transmission Ratio	$i_{spring2motor} = \frac{(q_{joint} + \sigma) \cdot r}{(sw - L \cdot \sqrt{(1 - 4 \cdot L^2 / (s\theta - (q_{joint} + \sigma) \cdot r)^2})^2)}$