

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

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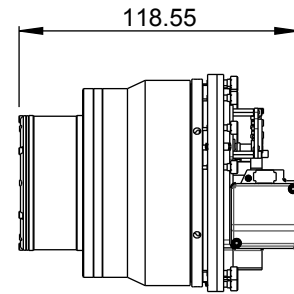
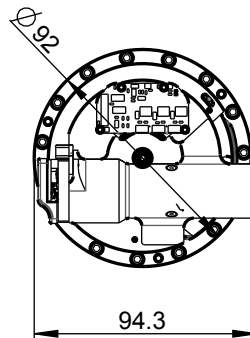
“DLR FloatingSpringJoint (FSJ) datasheet”

Multimedia Extension #1

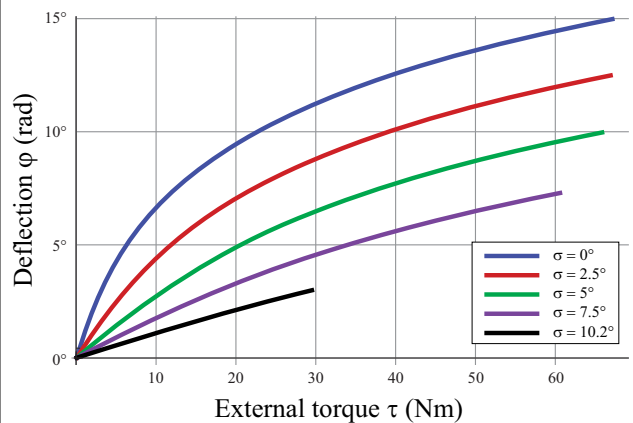
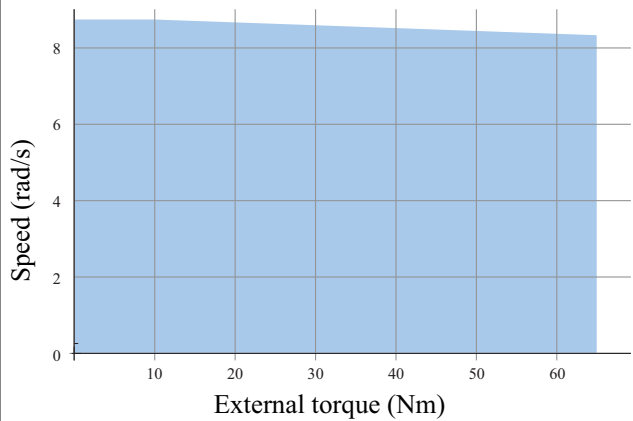
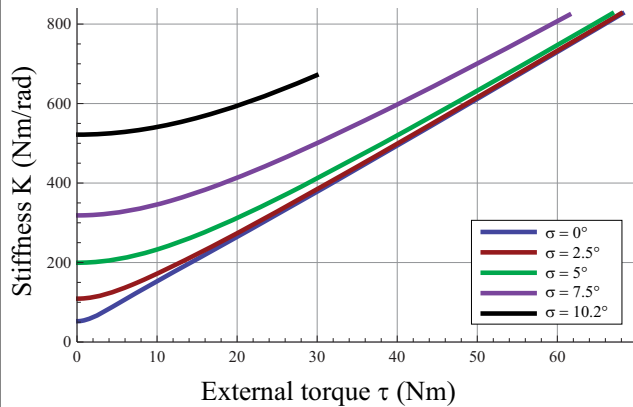
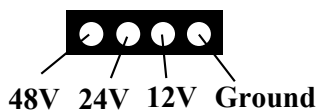
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# DLR Floating Spring Joint (FSJ)

## Adjustable Stiffness Joint

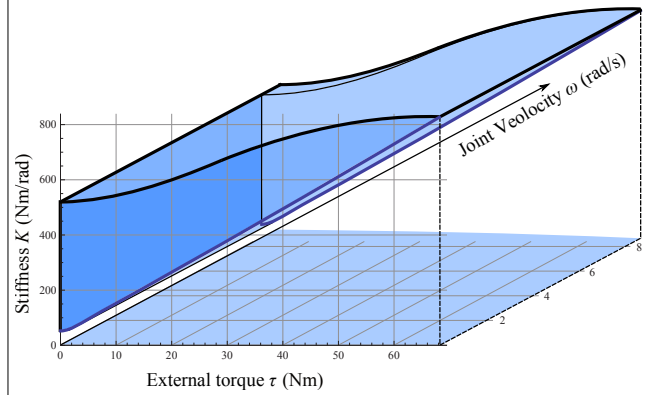
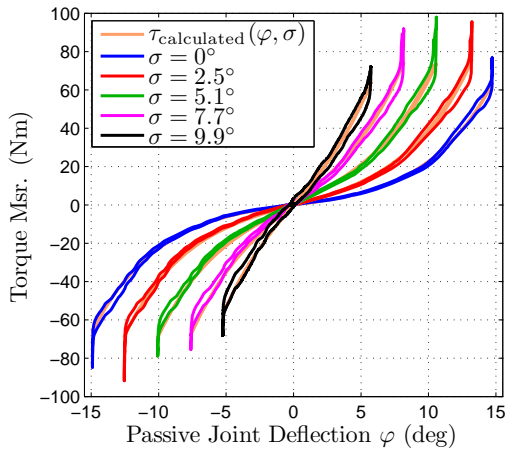


Operating Data			
#	(quantity)	(unit)	(value)
Mechanical			
1	Continuous Output Power	[W]	266.4
2	Nominal Torque	[Nm]	31.3
3	Nominal Speed	[rad/s]	8.51
4	Nominal Stiffness Variation Time	with no load	[s] 0.33
5		with nominal torque	[s] 0.33
6	Peak (Maximum) Torque	[Nm]	67
7	Maximum Speed	[rad/s]	8.51
8	Maximum Stiffness	[Nm/rad]	826
9	Minimum Stiffness	[Nm/rad]	52.4
10	Maximum Elastic Energy	[J]	5.3
11	Maximum Torque Hysteresis	[%]	20
12	Maximum deflection	with max. stiffness	[°] 3
13		with min. stiffness	[°] 15
14	Active Rotation Angle	[°]	180
15	Angular Resolution	[°]	0.0031
16	Weight	[Kg]	1,41
Electrical			
17	Nominal Voltage	[V]	48; 24
18	Nominal Current	[A]	10; 3
19	Maximum Current	[A]	24; 9
Control			
20	Voltage Supply	[V]	12
21	Nominal Current	[A]	1
22	I/O protocol	[]	spacewire

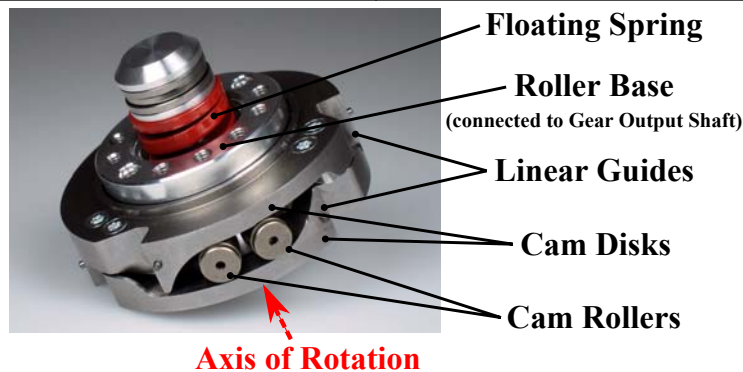
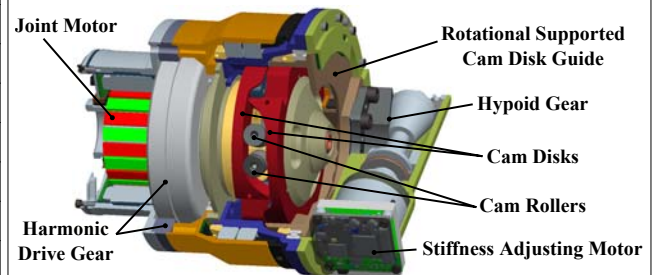
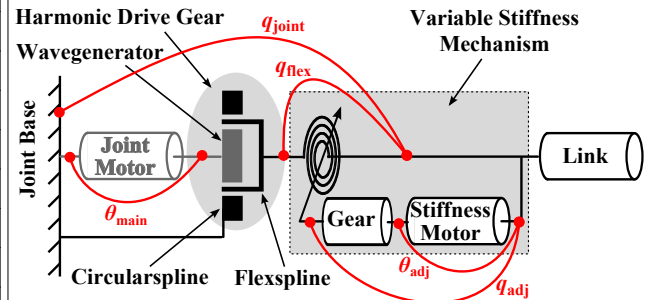


# DLR Floating Spring Joint (FSJ)

## Additional Characteristics

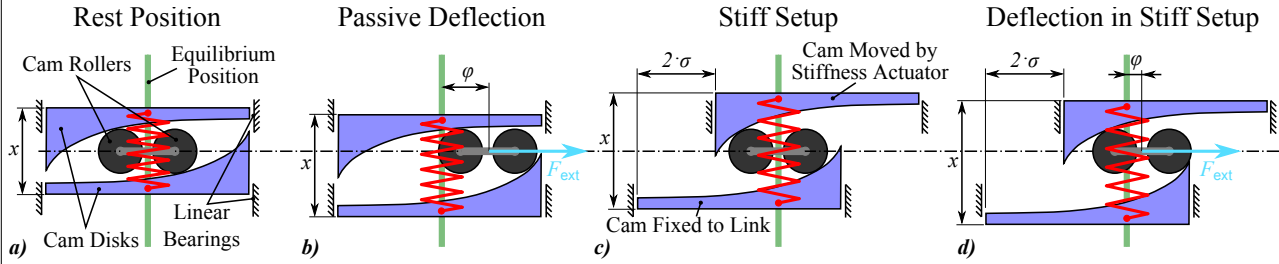


Additional sensors data			
#	(quantity)	(unit)	(value)
<b>Sensor <math>\theta_{\text{main}}</math></b>			
a0			
a1	Resolution	[bit]	12
a2	Range	[turns]	multi
a3	I/O protocol		Biss
<b>Sensor <math>\theta_{\text{adj}}</math></b>			
bx	Resolution	[bit]	12
by	Range	[turns]	multi
bz	I/O protocol		Biss
<b>Sensor <math>q_{\text{joint}}</math></b>			
cx	Resolution	[bit]	16
cy	Range	[°]	205
cz	I/O protocol		Biss
<b>Sensor <math>q_{\text{flex}}</math></b>			
dx	Resolution	[bit]	15
dy	Range	[°]	30
dz	I/O protocol		Biss
<b>Sensor <math>q_{\text{adj}}</math></b>			
ex	Resolution	[bit]	13
ey	Range	[°]	23
ez	I/O protocol		Biss



# DLR Floating Spring Joint (FSJ)

## Model



## Mathematical model

101	Recoil Point Function	$\varepsilon(q_{main}, q_{adj}) = q_{main} - \frac{1}{2} q_{adj}$
102	Energy Function	$H(q_{main}, q_{adj}, q_{joint}) = \int_0^{\varphi} \tau d\varphi$
103	Output Torque Function	$\tau(q_{main}, q_{adj}, q_{joint}) = 218 \cdot (\dot{x}(\varphi + \sigma) - \dot{x}(-\varphi + \sigma)) \cdot (x(\varphi + \sigma) + x(-\varphi + \sigma))$
104	Output Stiffness Function	$k(q_{main}, q_{adj}, q_{joint}) = 218 \cdot ((\dot{x}(\varphi + \sigma) - \dot{x}(-\varphi + \sigma))^2 + (x(\varphi + \sigma) + x(-\varphi + \sigma))(\ddot{x}(\varphi + \sigma) + \ddot{x}(-\varphi + \sigma)))$

$$q_{main} = -80 \cdot \theta_{main}$$

Passive joint deflection  $\varphi = q_{flex} - (\varepsilon - q_{main})$  and stiffness preset  $\sigma = \frac{1}{2} q_{adj}$ .

The cam disc shape  $x(\varphi, \sigma)$  was numerically calculated.  $\dot{x}(\varphi, \sigma) = \frac{\partial x}{\partial \varphi}$ ,  $\ddot{x}(\varphi, \sigma) = \frac{\partial \dot{x}}{\partial \varphi}$ .