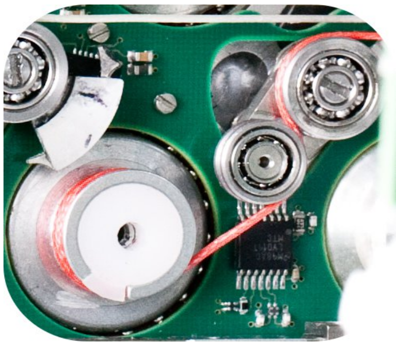
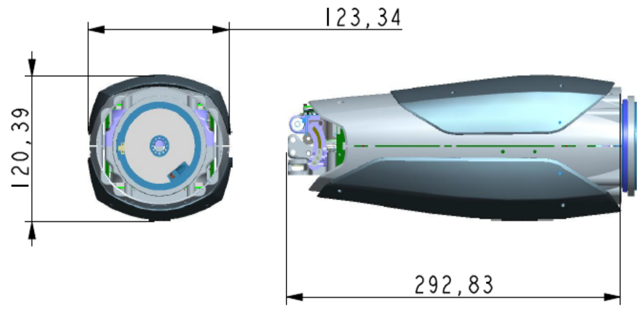
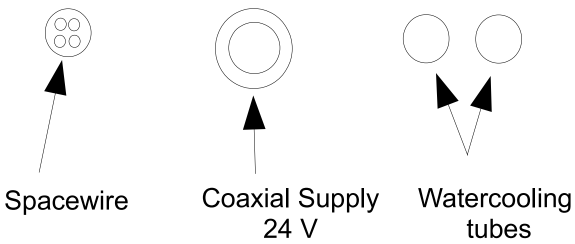
# FAS A flexible Antagonistic spring element

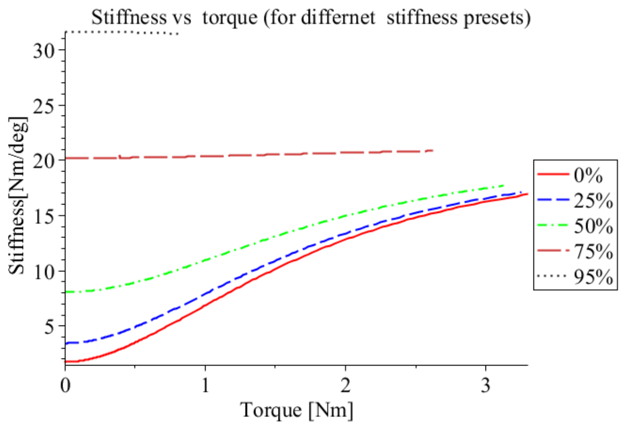
## Antagonistic finger joint

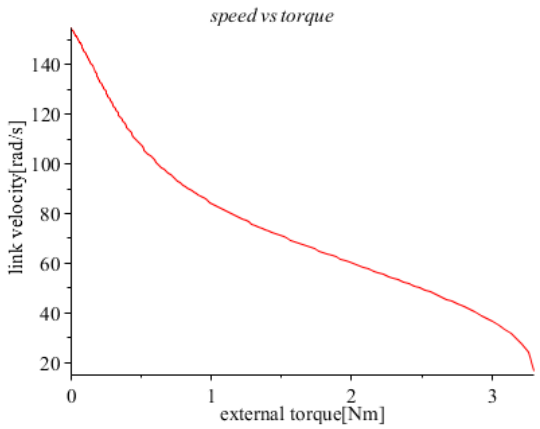


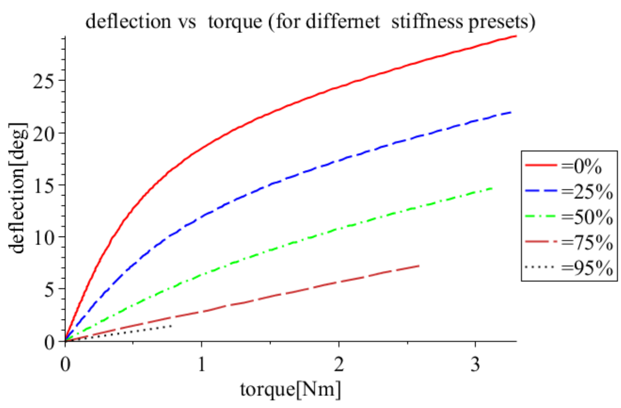



| # | (quantity) | | (unit) | (value) |
|---|---|---|---|---|
| **Operating Data** | | | | |
| **Mechanical** | | | | |
| 1 | Continuous Output Power | | [W] | 67,2 |
| 2 | Nominal Torque | | [Nm] | 2,2 |
| 3 | Nominal Speed | | [rad/s] | 16,74 |
| 4 | Nominal Stiffness Variation Time | with no load | [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 |



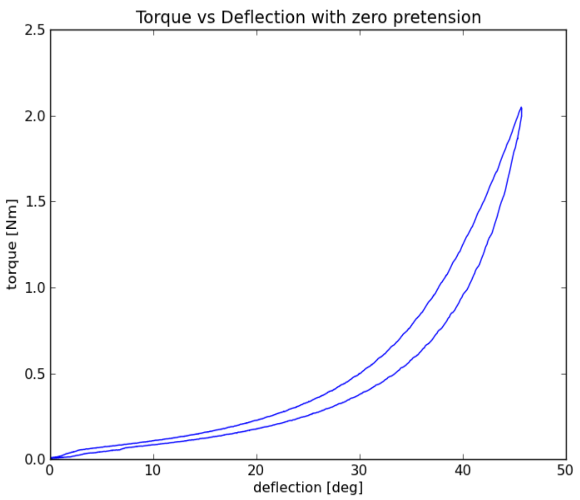



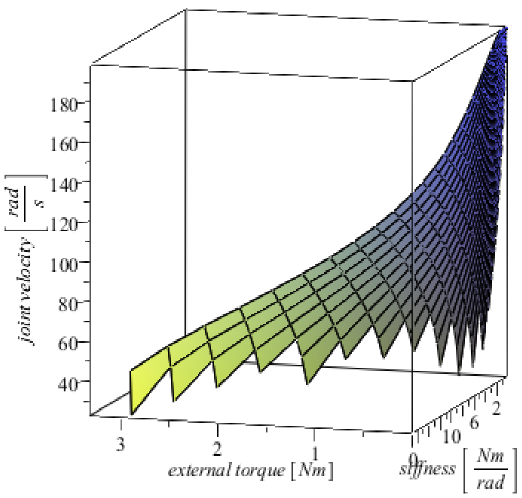



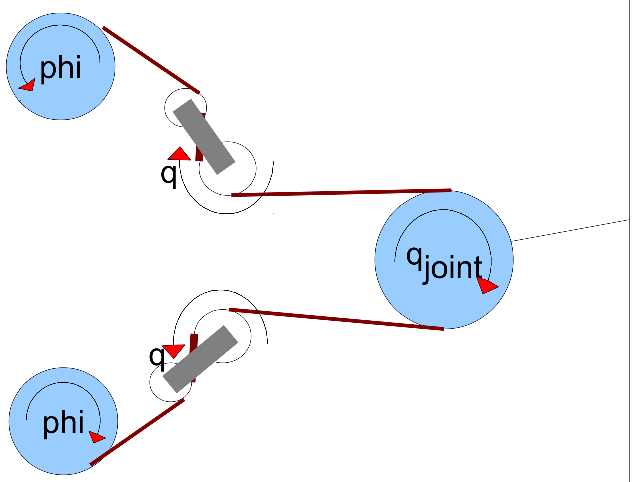
# Actuator Name (repetition)

## 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.

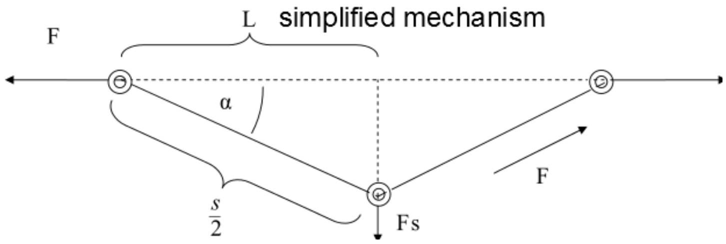
Also an embedded supply layer is integrated to power the motors and to safe connectors.

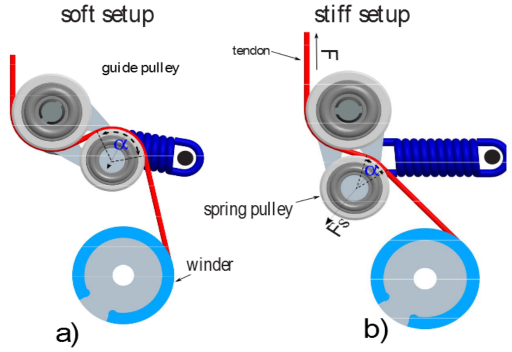
The velocity vs torque curve shows the snipping speed of the finger. The finger is elongated in the PIP and DIP joint.

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 | $H(\sigma,q_{joint})=\frac{c}{2}\cdot(sw-L\cdot\sqrt{(1-4L^2(s0-(q_{joint}+\sigma)r)^2)})^2-(sw-L\cdot\sqrt{(1-\frac{4L^2}{(s0-(-q_{joint}+\sigma)r)^2}))}^2$ |
| 103 | Output Torque Function | $\tau(q_{joint},\sigma)=\frac{-(0.5\cdot c(sw\cdot L\cdot\sqrt{(1-\frac{(4\cdot L^2)}{(s0-(q_{joint}+\sigma)\cdot r)^2}}))\cdot r)}{\sqrt{(1-\frac{(4\cdot L^2)}{(s0-(q_{joint}+\sigma)\cdot r)^2})}}+\frac{(0.5\cdot c(sw\cdot L\cdot\sqrt{(1-\frac{(4\cdot L^2)}{(s0-(-q_{joint}+\sigma)\cdot r)^2}}))\cdot r)}{\sqrt{(1-\frac{(4\cdot L^2)}{(s0-(-q_{joint}+\sigma)\cdot r)^2})}}$ |
| 104 | Output Stiffness Function | $k(q_{joint},\sigma)=\frac{d\,\tau}{d(q_{joint},\sigma)}$ |
| 106 | Springs to Motors Transmission Ratio | $i_{spring2motor}=\frac{(q_{joint}+\sigma)\cdot r}{(sw-L\cdot\sqrt{(1-4\cdot L^2/(s0-(q_{joint}+\sigma)\cdot r)^2)})^2}$ |