Part Selection

For the mechanism elements which transmit torque we selected a standard steel from the Autodesk Material Library to guarantee that they will have enough strength. This includes all shafts, gears, keys and retaining rings.

The frame, bushings, cover plates and servomotor mounts were designed to be light weight but still rigid. A reasonable choice of material was 6061 aluminum alloy. As these parts are none standard, production of these parts should be easy and inexpensive. Most parts that will be made from aluminum plates are either die pressed, cut and/or bent into shape.

The bolted connections (bolts, nuts and washers) are composed of standardized elements.

For the bearings, rough calculation-based assumptions lead to the selection of SKF W 638/4 XR-2Z deep groove ball bearings. They are located in the place of contact between any bodies rotating relative to each other.

As for the motors, the end joints are powered by 3564_B brushless DC servomotor and the base joint by 4490_B brushless DC servomotor. Their large stall torques makes them adequate for the job.

The end joints function only to obtain a good positioning grip, while the larger base joints will provide the necessary torque to attain a sustainable grip. The end joints will also position themselves in order to have a mechanical advantage by acquiring such an angle that the pressing force is transferred to the joint shaft as much as possible. The worm gear also provides an additional locking mechanism.

In the table below we placed selected standardized elements

Element	**Source**
4490_B brushless DC servomotor	https://fmcc.faulhaber.com/resources/img/EN_4490_B_FMM.PDF

Brushless DC-Servomotors 190 mNm

2 Pole Technology 232 W

Series 4490 ... B

Values at 22°C and nominal voltage		4490 H	024 B	036 B	048 B	
1	Nominal voltage	U_N	24	36	48	V
2	Terminal resistance, phase-phase	R	0,22	0,44	0,7	Ω
3	Efficiency, max.	$\eta_{max.}$	87	87	87	%
4	No-load speed	n_0	9 700	10 400	10 800	min^{-1}
5	No-load current, typ. (with shaft ø 6 mm)	I_0	0,527	0,397	0,317	A
6	Stall torque	M_H	2 635	2 760	2 978	mNm
7	Friction torque, static	C_0	4,96	4,96	4,96	mNm
8	Friction torque, dynamic	C_V	$7{,}72 \cdot 10^{-4}$	$7{,}72 \cdot 10^{-4}$	$7{,}72 \cdot 10^{-4}$	mNm/min^{-1}
9	Speed constant	k_n	395	283	220	min^{-1}/V
10	Back-EMF constant	k_E	2,53	3,54	4,56	mV/min^{-1}
11	Torque constant	k_M	24,2	33,8	43,5	mNm/A
12	Current constant	k_I	0,041	0,03	0,023	A/mNm
13	Slope of n-M curve	$\Delta n/\Delta M$	3,6	3,7	3,5	min^{-1}/mNm
14	Terminal inductance, phase-phase	L	73	142	235	µH
15	Mechanical time constant	τ_m	4,9	5	4,8	ms
16	Rotor inertia	J	130	130	130	gcm^2
17	Angular acceleration	$\alpha_{max.}$	203	212	229	$\cdot 10^3 rad/s^2$
18	Thermal resistance	R_{th1} / R_{th2}	0,96 / 3,9			K/W
19	Thermal time constant	τ_{w1} / τ_{w2}	23 / 1 222			s
20	Operating temperature range:					
	– motor		-30 ... +125			°C
	– winding, max. permissible		+125			°C
21	Shaft bearings		ball bearings, preloaded			

Element	Source
3564_B brushless DC servomotor	https://fmcc.faulhaber.com/resources/img/EN_3564_B_FMM.PDF

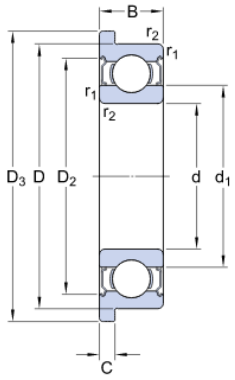
Brushless DC-Servomotors — 66 mNm

2 Pole Technology — 126 W

Series 3564 ... B

Values at 22°C and nominal voltage		3564 K	012 B	024 B	036 B	048 B	
1	Nominal voltage	U_N	12	24	36	48	V
2	Terminal resistance, phase-phase	R	0,56	1,1	2,61	4,1	Ω
3	Efficiency, max.	$\eta_{max.}$	82	83	83	83	%
4	No-load speed	n_0	8 300	11 500	11 600	12 800	min^{-1}
5	No-load current, typ. (with shaft ø 4 mm)	I_0	0,198	0,166	0,112	0,099	A
6	Stall torque	M_H	293	432	408	418	mNm
7	Friction torque, static	C_0	1,2	1,2	1,2	1,2	mNm
8	Friction torque, dynamic	C_V	$1{,}8 \cdot 10^{-4}$	$1{,}8 \cdot 10^{-4}$	$1{,}8 \cdot 10^{-4}$	$1{,}8 \cdot 10^{-4}$	mNm/min^{-1}
9	Speed constant	k_n	696	481	323	266	min^{-1}/V
10	Back-EMF constant	k_E	1,44	2,08	3,1	3,75	mV/min^{-1}
11	Torque constant	k_M	13,7	19,9	29,6	35,8	mNm/A
12	Current constant	k_I	0,073	0,05	0,034	0,028	A/mNm
13	Slope of n-M curve	$\Delta n / \Delta M$	28	27	28	31	min^{-1}/mNm
14	Terminal inductance, phase-phase	L	90	190	410	640	µH
15	Mechanical time constant	τ_m	10,4	9,7	10,4	11,1	ms
16	Rotor inertia	J	34,9	34,9	34,9	34,9	gcm^2
17	Angular acceleration	$\alpha_{max.}$	84	124	117	120	$\cdot 10^3 rad/s^2$
18	Thermal resistance	R_{th1} / R_{th2}	1,6 / 6,2				K/W
19	Thermal time constant	τ_{w1} / τ_{w2}	15,4 / 820				s
20	Operating temperature range:						
	– motor		-30 ... +125				°C
	– winding, max. permissible		+125				°C
21	Shaft bearings		ball bearings, preloaded				

SKF W 638/4 XR-2Z deep grove ball bearing	http://www.skf.com/group/products/bearings-units-housings/ball-bearings/deep-groove-ball-bearings/deep-groove-ball-bearings/index.html?designation=W%20638/4%20XR-2Z



d		4	mm
D		10	mm
B		4	mm
d_1	≈	5.9	mm
D_2	≈	8.8	mm
D_3		11.6	mm
C		0.8	mm
$r_{1,2}$	min.	0.15	mm