4 Project Planning Notes for Servo Gearmotors

4.1 Additional documentation

In addition to the information in this publication, SEW-EURODRIVE offers extensive documentation covering the entire topic of electrical drive engineering. These are mainly the publications in the "Drive Engineering – Practical Implementation" series as well as the manuals and catalogs for electronically controlled drives.

You will find additional links to a wide selection of our documentation in many languages for download on the SEW-EURODRIVE homepage (http://www.sew-eurodrive.com). The list below includes other documents that are of interest in terms of project planning. You can order these publications from SEW-EURODRIVE.

Technical data for motors and gear units

The following documents are available from SEW-EURODRIVE in addition to this "Asynchronous Servo Gearmotors" catalog:

- "AC Motors" price catalog/catalog
- "Servo Gear Units" price catalog/catalog
- "Gear Units" price catalog/catalog
- "AC Motors Inverter Assignments and Characteristic Curves" manual

Drive Engineering Practical Implementation

- Project Planning for Drives
- Controlled AC Drives
- SEW encoder systems
- Servo technology
- EMC in Drive Engineering
- Explosion-Proof Drives to EU Directive 94/9/EC
- SEW Disk Brakes

Electronics documentation

- MOVIDRIVE® MDX60/61B system manual
- MOVIAXIS® MX system manual

Mechanical brakes

- "AC Motors" price catalog/catalog

4.2 Data for drive and gear unit selection

The data of the application must be known for projecting a drive. The abbreviations used for project planning are summarized in the following table:

Designation	Meaning	Unit
φ	Circumferential backlash	`
h	Gear unit efficiency for M_{apk}	
a, b, f	Gear unit constants as regards the overhung load conversion	mm
c	Gear unit constants as regards the overhung load conversion	Nmm
a_0, a_1, a_2	Gear unit constants as regards the rise in temperature in the gear unit	
F_A	Axial load (tension and compression) on the output shaft	N
f_k	Speed ratio	
F_R	Overhung load on the output shaft	N
F_{Rapk}	Maximum permitted overhung load at the output shaft for short-time duty (load application point is the middle of the shaft end)	N
F_{Ramax}	Maximum permitted overhung load at the output shaft for continuous duty (load application point is the middle of the shaft end)	N
F_{Repk}	Maximum permitted overhung load at the input shaft for short-time duty (load application point is the middle of the shaft end)	N
F_{Remax}	Maximum permitted overhung load at the input shaft for continuous duty (load application point is the middle of the shaft end)	N
H	Installation altitude	m above sea level
I_0	Current consumption of the motor at M_0	A
I_{max}	Maximum permitted motor current (root-mean-square value)	A
Ins. cl.	Thermal classification of the motor	
i	Gear unit reduction ratio	
IM	Mounting position of the gear unit (international mounting position) M1 - M6	
IP..	Degree of protection according to IEC60034-5	
J_A	Mass moment of inertia of the adapter	kgm^2
J_G	Mass moment of inertia of the gear unit	kgm^2
J_{ext}	Mass moment of inertia (external) reduced on motor shaft	kgm^2
J_{mot}	Mass moment of inertia of the motor	kgm^2
J_L	Mass moment of inertia of the load	kgm^2
k	Inertia ratio J_{ext} / / J_{Mot}	
l	Length of output shaft	mm
M_1 - M_n	Output torque in time period t_1 to t_n	Nm
M_0	Thermally permitted output torque of the motor in continuous duty at low speed (not to be confused with standstill torque)	Nm
M_a^{DYN}	Dynamic output torque assumed for the drive in project planning	Nm
M_{aeff}	Effective torque for component testing calculated in project planning	Nm
M_{akub}	Effective torque for bearing testing calculated in project planning	Nm
M_{amax}	Maximum permitted output torque for continuous duty	Nm
M_{apk}	Maximum permitted torque for short-time duty	Nm
$M_{aNOTAUS}$	Maximum permitted emergency stop torque, max. 1000 emergency stops	Nm
M_{ath}	Effective torque for thermal testing calculated in project planning	Nm
M_B	Rated brake torque	Nm
M_{pk}	Dynamic limit torque of the servomotor	Nm

Table continued on next page.

Designation	Meaning	Unit
M_{eff}	Effective torque requirement (in relation to the motor)	Nm
M_{max}	Maximum output torque assumed for the drive in project planning	Nm
ML	Mounting location (UL)	
n_{apk}	Maximum permitted output speed for short-time duty	rpm
n_{epk}	Maximum permitted input speed for short-time duty	rpm
n_{em}	Mean input speed	rpm
n_{am}	Mean output speed	rpm
n_{ak}	Breakpoint speed (output)	rpm
n_N	Rated speed	rpm
n_1 - n_n	Output speed in time period t_1 to t_n	rpm
n_{etn_pk}	Maximum input speed in section	rpm
P_{Br}	Braking power	W
P_{Br_pk}	Peak braking power	W
P_{Br_eff}	Effective braking power	W
P_{Br_tn}	Braking power in section t_n	W
S.., ..% cdf	Duty type and cyclic duration factor (cdf) or exact load cycle can be entered.	s
t_1 - t_n	Time period 1 to n	s
t_z	Cycle time	s
T_{Amb}	Ambient temperature	°C
U_{sys}	System voltage, voltage of the supplying inverter	V
U_{Br}	Operating voltage of the brake	V
x	Distance between overhung load application point and shaft shoulder	mm

Determining the application data

It is necessary to have data on the machine to be driven (mass, speed, setting range, etc.) to project the drive correctly.

These data help determine the required power, torque and speed. Refer to the SEW publication "Drive Engineering Practical Implementation/Drive Planning" or the SEW project planning tool SEW Workbench for assistance.

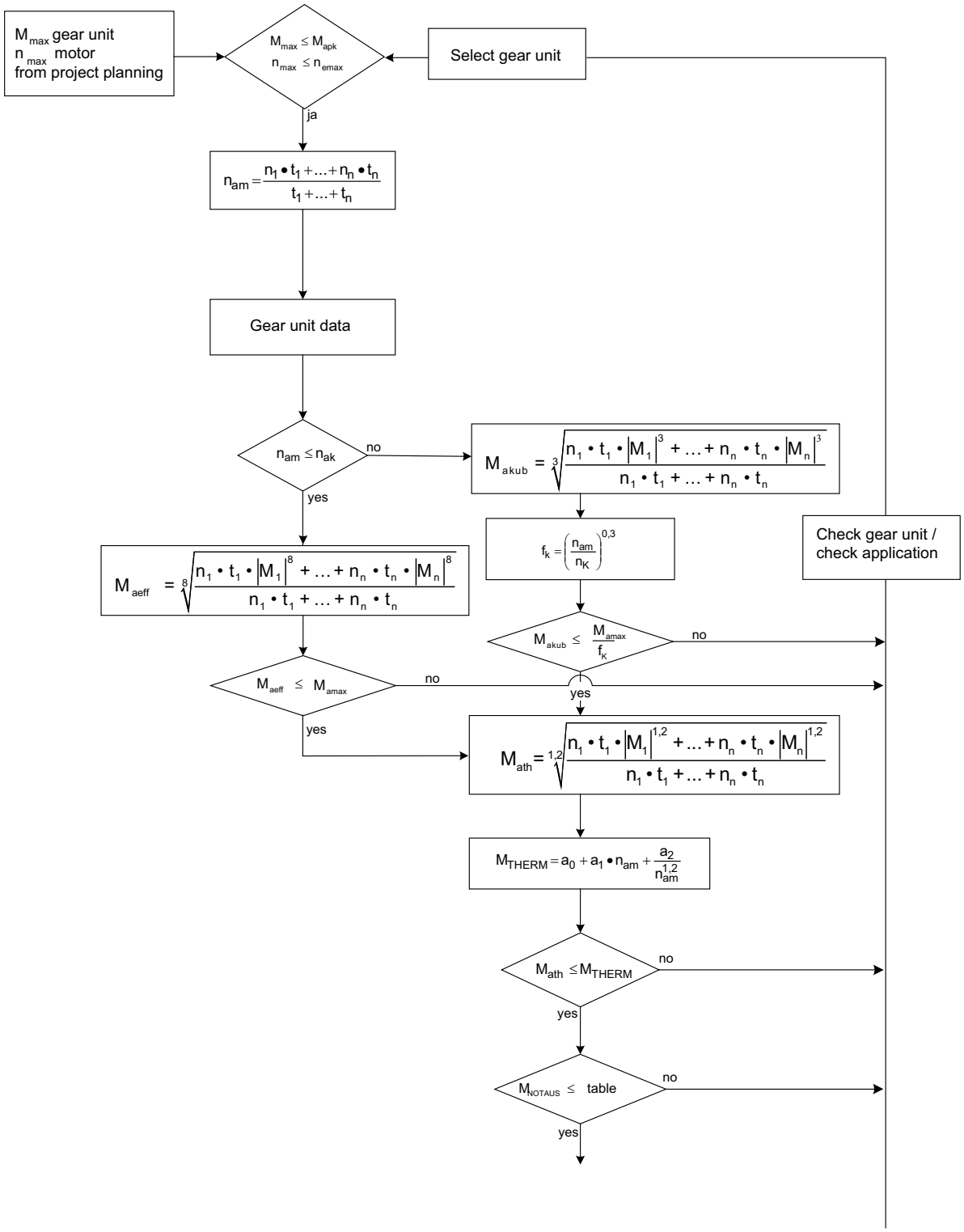
Selecting the correct drive

The appropriate drive can be selected once the power and speed of the drive have been calculated and with regard to mechanical requirements.

4.3 Project planning procedure

The following flowcharts show a schematic view of the project planning procedure of a servo gear unit for a positioning drive in S3 duty cycle.

Project planning procedure part 1, servo gear units



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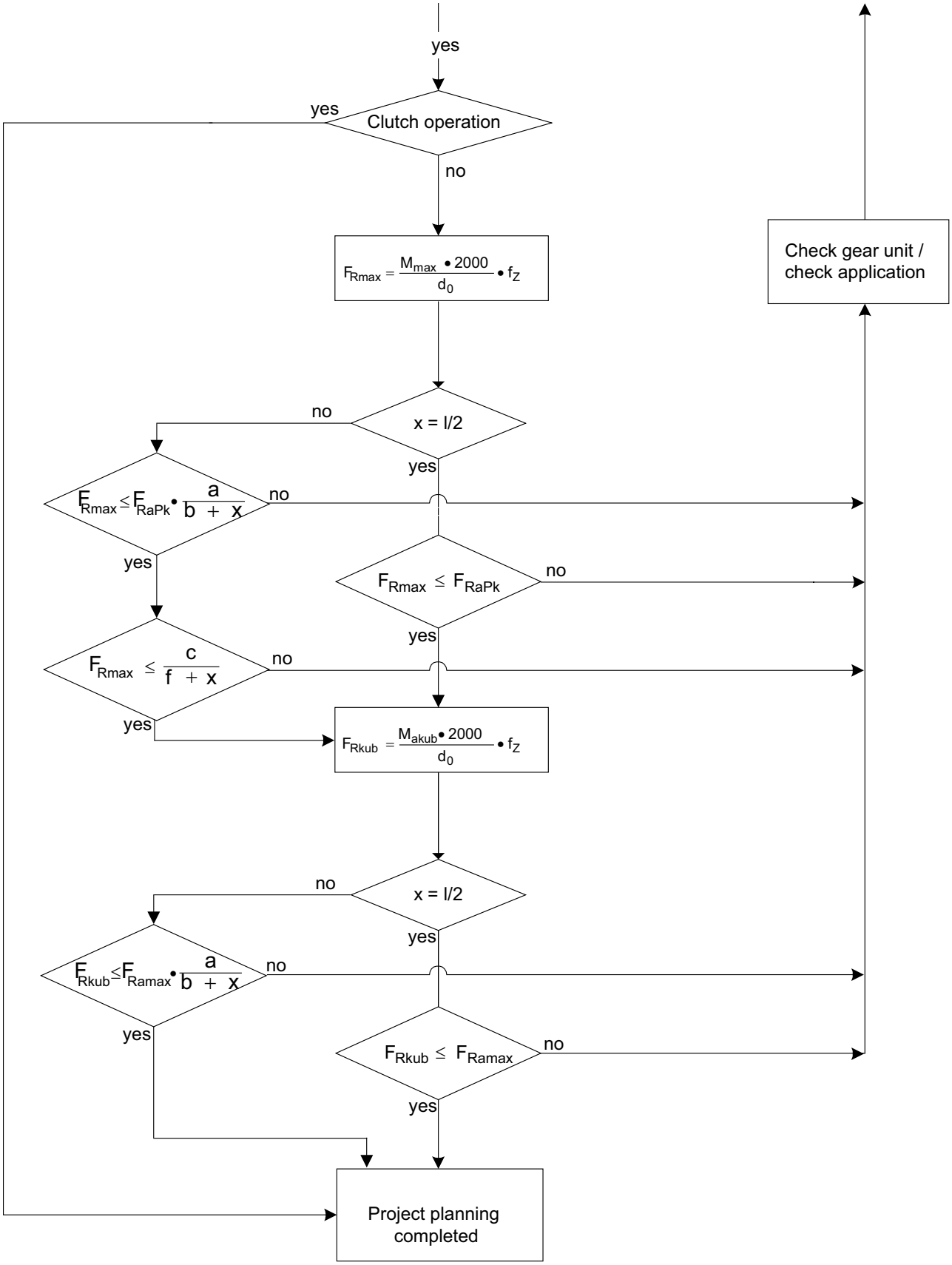
* For thermal project planning of R, F, K, S, W gear units, please contact SEW-EURODRIVE.

Project planning procedure part 2, servo gear units



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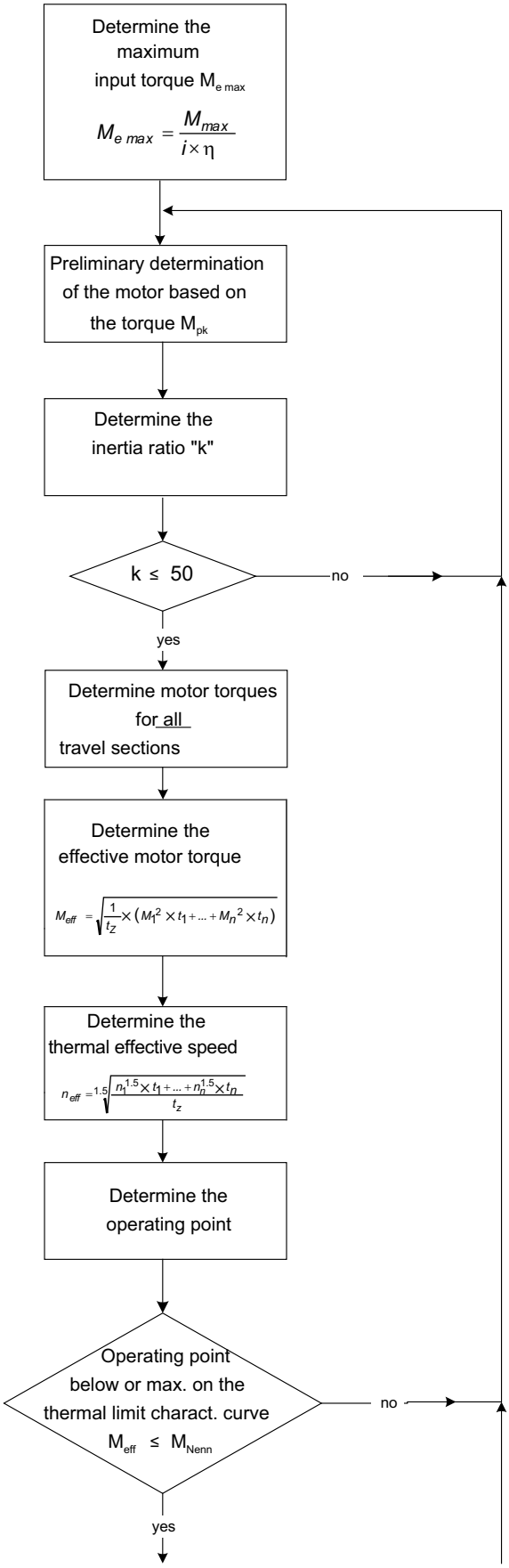
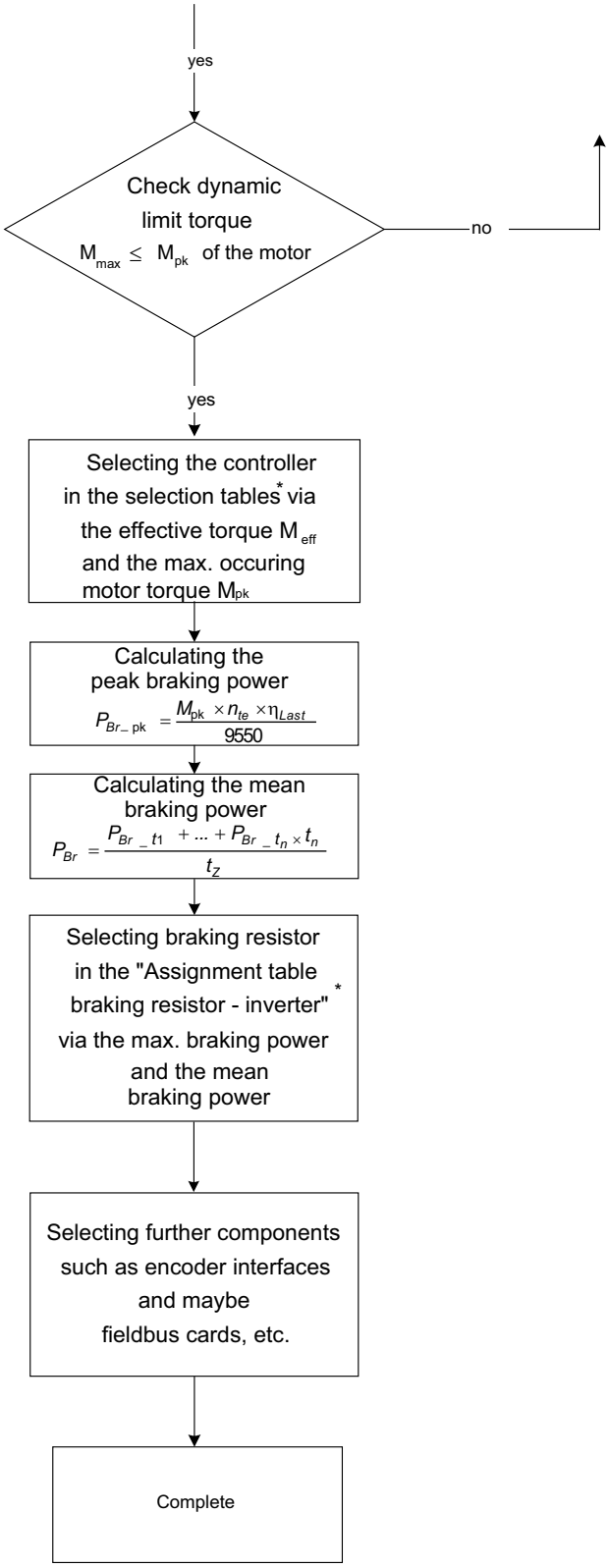
Project planning procedure part 3, servomotors



Project planning procedure part 4, servomotors



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* MOVIDRIVE® system manual, MOVIAXIS® system manual

4.4 Project planning information

Efficiency of the gear units

General

The efficiency of gear units is mainly determined by the gearing and bearing friction. Keep in mind that the starting efficiency of a gear unit is always less than its efficiency at operating speed. This applies in particular to helical-worm and SPIROPLAN® right-angle gearmotors.

R, F, K gear units

The efficiency of helical, parallel shaft and helical-bevel gear units varies with the number of gear stages, between 96% (3-stage), 97% (2-stage) and 98% (1-stage).

S and W gear units

The gearing in helical-worm and SPIROPLAN® gear units produces a high proportion of sliding friction. As a result, these gear units have higher gearing losses than R, F or K gear units and therefore lower efficiency.

The efficiency depends on the following factors:

- Gear ratio of the helical-worm or SPIROPLAN® stage
- Input speed
- Gear unit temperature

Helical-worm gear units from SEW-EURODRIVE are helical gear/worm combinations that are significantly more efficient than plain worm gear units.

The efficiency η can be < 0.5 if the helical-worm gear stage has a very high gear ratio.

The SPIROPLAN® gear unit W37/W47 from SEW-EURODRIVE has an efficiency of more than 90%, which drops only slightly even for large gear unit ratios.

Self-locking

Retrodriving torques on helical-worm or SPIROPLAN® gear units produce an efficiency of $\eta = 2 - 1/\eta$, which is significantly less favorable than the forward efficiency η. The helical-worm or SPIROPLAN® gear unit is self-locking if the forward efficiency is $\eta \leq 0.5$. Some SPIROPLAN® gear units are dynamically self-locking. Contact SEW-EURODRIVE if you want to make technical use of the braking effect of self-locking characteristics.

	INFORMATION
	Note that the self-locking effect of helical-worm and SPIROPLAN® gear units is not permitted as the sole safety function for hoists.

Run-in phase

The tooth flanks of new helical-worm and SPIROPLAN® gear units are not yet completely smooth. This fact results in a greater friction angle and less efficiency than during later operation. This effect intensifies with increasing gear unit ratio. Subtract the following values from the listed efficiency during the running-in phase:

	Worm	
	i range	**η reduction**
1-start	ca. 50 - 280	ca. 12%
2-start	ca. 20 - 75	ca. 6%
3-start	ca. 20 - 90	ca. 3%
5-start	ca. 6 - 25	ca. 3%
6-start	ca. 7 - 25	ca. 2%

SPIROPLAN® W..	
i range	**η reduction**
ca. 30 - 70	ca. 8%
ca. 10 - 30	ca. 5%
ca. 3 - 10	ca. 3%

The run-in phase usually lasts 48 hours. Helical-worm and SPRIOPLAN® gear units achieve their listed rated efficiency values when:

- The gear unit has been completely run-in,
- The gear unit has reached nominal operating temperature,
- The recommended lubricant has been filled in, and
- The gear unit is operating in the rated load range.

Churning losses

With certain gear unit mounting positions, the first gearing stage is completely immersed in the lubricant, see chapter "Gear Unit Mounting positions" on page 68. When the circumferential velocity of the input stage is high, considerable churning losses occur in larger gear units that must be taken into account. Contact SEW-EURODRIVE if you wish to use gear units of this type.

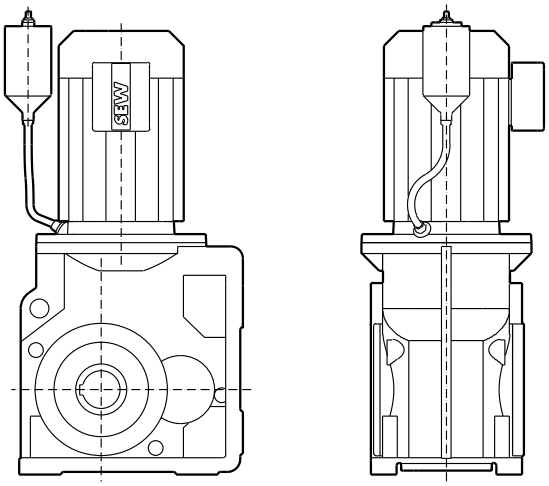
To reduce churning losses to a minimum, use gear units in M1 mounting position.

Oil expansion tank

The oil expansion tank allows the lubricant/air space of the gear unit to expand. This means no lubricant can escape the breather valve at high operating temperatures.

SEW-EURODRIVE recommends to use oil expansion tanks for gear units and gearmotors in M4 mounting position and for input speeds > 2000 rpm.

The following figure shows an example of a gearmotor with oil expansion tank.



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The oil expansion tank is provided as assembly kit. It is intended for mounting onto the gearmotor. However, if installation space is limited or if the expansion tank is intended for gear units without motor, it can be mounted to nearby machine parts.

For further information, please contact your SEW-EURODRIVE sales representative.

Overhung and axial loads

Determining overhung loads

An important factor for determining the resulting overhung load is the type of transmission element mounted to the shaft end. The following transmission element factors f_Z have to be considered for various transmission elements.

Transmission element	Transmission element factor f_Z	Comments
Gears	1.15	< 17 teeth
Chain sprockets	1.40	< 13 teeth
Chain sprockets	1.25	< 20 teeth
Narrow V-belt pulleys	1.75	Influence of the pre-tensioning
Flat belt pulleys	2.50	Influence of the pre-tensioning
Toothed belt pulleys	2.00 - 2.50	Influence of the pre-tensioning
Gear rack pinion, pre-tensioned	2.00	Influence of the pre-tensioning
Gear rack pinion, not pre-tensioned	1.15	< 17 teeth

The overhung load exerted on the motor or gear shaft is calculated as follows:

$$F_R = \frac{M_d \cdot 2000}{d_0} \cdot f_Z$$

F_R = Overhung load in N
M_d = Torque in Nm
d_0 = Mean diameter of the installed transmission element in mm
f_Z = Transmission element factor

Permitted overhung load

The basis for determining the permitted overhung loads is the calculation of the rated bearing service life L_{10h} of the rolling bearings (according to ISO 281).

For special operating conditions, the permitted overhung loads can be determined with regard to the modified service life L_{na} on request.

The permitted overhung loads F_{Ra} for the output shafts of foot-mounted gear units with a solid shaft are listed in the selection tables for gearmotors. Contact SEW-EURODRIVE in case of other versions.

INFORMATION

The values refer to force applied to the center of the shaft end (in right-angle gear units as viewed onto the drive end). The values for the force application angle α and direction of rotation are based on the most unfavorable conditions.

	INFORMATION
	Reduction of overhung loads • Only 50% of the F_{Ramax} and F_{Rapk} values specified in the selection tables are permitted in mounting positions M1 and M3 with wall attachment on the front face for K and S gear units. • Helical-bevel gearmotors K167 and K187 in mounting positions M1 to M4: A maximum of 50% of the overhung load F_{Ramax} specified in the selection tables in the case of gear unit mounting other than as shown in the mounting position sheets. • Foot and flange-mounted helical gearmotors (R..F): A maximum of 50% of the overhung load F_{Ramax} specified in the selection tables in the case of torque transmission via the flange mounting.

Higher permitted overhung loads

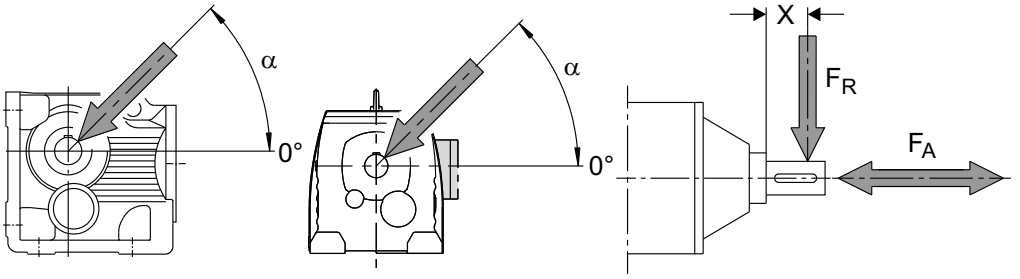
Exactly considering the force application angle α and the direction of rotation makes it possible to achieve a higher overhung load than listed in the selection tables.

Higher output shaft loads are permitted if heavy duty bearings are installed, especially with R, F and K gear units.

Contact SEW-EURODRIVE in such cases.

Definition of force application

The force application is defined according to the following figure:



F_X = Permitted overhung load at point x in N

F_A = Permitted axial load in N

Permitted axial load

If there is no overhung load, then an axial force F_A (tension or compression) amounting to 50% of the overhung load given in the selection tables is permitted. This condition applies to the following gearmotors:

- Helical gearmotors except for R..137... to R..167...
- Parallel shaft and helical-bevel gearmotors with solid shaft except for F97...
- Helical-worm gearmotors with solid shaft

	INFORMATION
	Contact SEW-EURODRIVE for all other types of gear units and in the event of significantly greater axial loads or combinations of overhung load and axial load.

Input side: Overhung load conversion for off-center force application

Important: only applies to gear units with input shaft assembly:

Please contact SEW-EURODRIVE for off-center force application on the drive end.

Output end: Overhung load conversion for off-center force application

The permitted overhung loads F_{Ramax} and F_{Rapk} specified in the data tables apply to force application at l / 2 (solid shaft) or to force application at the shaft end (hollow shaft). For any other distance of the force application point to the gear unit, it is necessary to determine the permitted overhung loads again according to the project planning procedure page 40 .

The following conditions must be met:

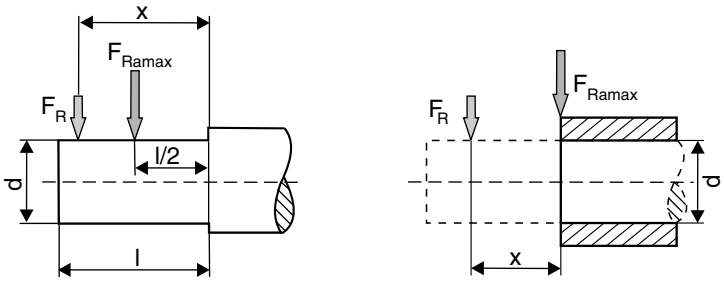
$$F_R \leq F_{Ra\max} \cdot \frac{a}{b+x}\ [N] \qquad F_R \leq \frac{c}{f+x}\ [N]$$

F_{Ramax} = Permitted overhung load [N]

x = Distance from the shaft shoulder to the force application point in mm

a, b, f = Gear unit constants for overhung load conversion in mm

c = Gear unit constant for overhung load conversion Nmm



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Gear unit constants for overhung load conversion

Gear unit type	a mm	b mm	c Nmm	f mm	d mm	l mm
RX57	43.5	23.5	1.51×10^5	34.2	20	40
RX67	52.5	27.5	2.42×10^5	39.7	25	50
RX77	60.5	30.5	1.95×10^5	0	30	60
RX87	73.5	33.5	7.69×10^5	48.9	40	80
RX97	86.5	36.5	1.43×10^6	53.9	50	100
RX107	102.5	42.5	2.47×10^6	62.3	60	120
R07	72.0	52.0	4.67×10^4	11	20	40
R17	88.5	68.5	6.527×10^4	17	20	40
R27	106.5	81.5	1.56×10^5	11.8	25	50
R37	118	93	1.24×10^5	0	25	50
R47	137	107	2.44×10^5	15	30	60
R57	147.5	112.5	3.77×10^5	18	35	70
R67	168.5	133.5	2.65×10^5	0	35	70
R77	173.7	133.7	3.97×10^5	0	40	80
R87	216.7	166.7	8.47×10^5	0	50	100
R97	255.5	195.5	1.06×10^6	0	60	120
R107	285.5	215.5	2.06×10^6	0	70	140
R137	343.5	258.5	4.58×10^6	0	90	170
R147	402	297	8.65×10^6	33	110	210
R167	450	345	1.26×10^7	0	120	210
F27	109.5	84.5	1.13×10^5	0	25	50
F37	123.5	98.5	1.07×10^5	0	25	50
F47	153.5	123.5	1.40×10^5	0	30	60
F57	170.7	135.7	2.70×10^5	0	35	70
F67	181.3	141.3	4.12×10^5	0	40	80
F77	215.8	165.8	7.87×10^5	0	50	100
F87	263	203	1.06×10^6	0	60	120
F97	350	280	2.09×10^6	0	70	140
F107	373.5	288.5	4.23×10^6	0	90	170
F127	442.5	337.5	9.45×10^6	0	110	210
F157	512	407	1.05×10^7	0	120	210
K37	123.5	98.5	1.30×10^5	0	25	50
K47	153.5	123.5	1.40×10^5	0	30	60
K57	169.7	134.7	2.70×10^5	0	35	70
K67	181.3	141.3	4.12×10^5	0	40	80
K77	215.8	165.8	7.69×10^5	0	50	100
K87	252	192	1.64×10^6	0	60	120
K97	319	249	2.80×10^6	0	70	140
K107	373.5	288.5	5.53×10^6	0	90	170
K127	443.5	338.5	8.31×10^6	0	110	210
K157	509	404	1.18×10^7	0	120	210
K167	621.5	496.5	1.88×10^7	0	160	250
K187	720.5	560.5	3.04×10^7	0	190	320
W37	121.1	101.1	$6.95 \xi 10^4$	0	20	40
W47	145.5	115.5	4.26×10^5	35.6	30	60
S37	118.5	98.5	6.0×10^4	0	20	40
S47	130	105	1.33×10^5	0	25	50
S57	150	120	2.14×10^5	0	30	60
S67	184	149	3.04×10^5	0	35	70
S77	224	179	5.26×10^5	0	45	90
S87	281.5	221.5	1.68×10^6	0	60	120
S97	326.3	256.3	2.54×10^6	0	70	140

Values for types not listed are available on request.

4.5 Project planning example

The travel drive of a storage/retrieval system is calculated in this project planning example.

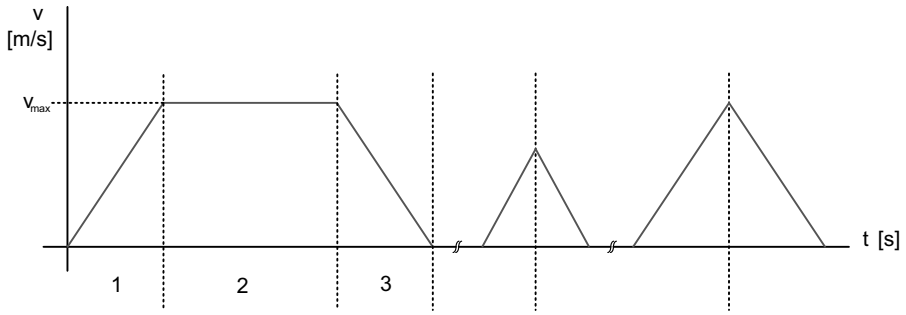
Reference data:

- Total moved mass: m_L = 15000 kg (trolley) + 2000 kg (useful load)
- Drive wheel diameter: d_0 = 445 mm
- Resistance to motion: F_F = 50 N/t
- Traveling velocity: V_{max} = 240 m/min
- Maximum occurring acceleration/deceleration: a_{max} = 0.5 m/s^2
- Travel time: 60%
- Mounting position: M4

An asynchronous DRL servomotor with a KV gear unit is used.

No overhung load acts on the output shaft.

Travel sections



Longest acceleration time in travel section 1

$$t_{1\max} = \frac{v_{\max}}{a_{\max}}$$
$$t_{1\max} = \frac{240\,\frac{m}{\min}}{0{,}5\,\frac{m}{s^2} \times 60\,\frac{s}{\min}}$$
$$t_{1\max} = 8\,s$$

M_{stat} for all travel sections

$$M_{stat} = \frac{m \times F_F \times d_0}{2000 \times \eta_L}$$
$$M_{stat} = \frac{(15000\,kg + 2000\,kg) \times 50\,\frac{N}{t} \times \frac{t}{1000kg} \times \frac{0{,}445\,m}{2}}{0{,}9}$$
$$M_{stat} = 210{,}14\,Nm$$

M_{dyn} during acceleration in travel section 1

$$M_{dyn} = \frac{m \times a \times \frac{d_0}{2}}{\eta_L}$$
$$M_{dyn} = \frac{(15000\,kg + 2000\,kg) \times 0{,}5\,\frac{m}{s^2} \times \frac{0{,}445\,m}{2}}{0{,}9}$$
$$M_{dyn} = 2101{,}39\,Nm$$

M_{dyn} during deceleration in travel section 3

$$M_{dyn} = m \times a \times \frac{d_0}{2} \times \eta_L$$
$$M_{dyn} = (15000\,kg + 2000\,kg) \times 0{,}5\,\frac{m}{s^2} \times \frac{0{,}445\,m}{2} \times 0{,}9$$
$$M_{dyn} = 1702{,}125\,Nm$$

M_{max} during acceleration in travel section 1

$$M_{\max} = M_{stat} + M_{dyn}$$
$$M_{\max} = 210{,}14\,Nm + 2101{,}39\,Nm$$
$$M_{\max} = 2311{,}53\,Nm$$

M_{dyn} during deceleration in travel section 3

$$M_{max} = M_{stat} + M_{dyn}$$
$$M_{max} = 210{,}14\ Nm + (-1702{,}125\ Nm)$$
$$M_{max} = -1491{,}99\ Nm$$

Maximum output speed

$$n_{a\ max} = \frac{V_{max}}{d_0 \times \pi}$$
$$n_{a\ max} = \frac{240\ \frac{m}{min}}{0{,}445\ m \times \pi}$$
$$n_{a\ max} = 171{,}67\ \frac{1}{min}$$

Gear ratio

The rated motor speed should be 2100 rpm.

$$i = \frac{n_N}{n_{a\ max}}$$
$$i = \frac{2100\ \frac{1}{min}}{171{,}67\ \frac{1}{min}}$$
$$i = 12{,}23$$

Gear unit pre-selection

The KV gear unit is selected based on the following values:

- i = 12.23
- M_{max} = 2311.53 Nm

DRL..							F_{Ramax}				F_{Rapk}			
n_e = 1400	i	M_{amax} [Nm]	M_{apk} [Nm]	$M_{aNotaus}$ [Nm]	n_{ak} [1/min]	J_G 10^{-4} [kgm^2]	K [N]	KF [N]	KA [N]	KAF [N]	K [N]	KF [N]	KA [N]	KAF [N]
K87 3	7.21	1300	1950	2210	250	46	13200	15100	4970	4970	28100	27000	30000	30000
	8.29	1400	2100	2380	205	35	13500	15600	4960	4960	27900	26900	30000	30000
	10.00	1500	2240	2550	180	26	14200	16400	5210	5210	27800	26700	30000	30000
	11.17	1500	2250	2550	188	22	14900	17100	5770	5770	27800	26700	30000	30000
	12.56	2000	3000	3400	223	42	14800	17000	5030	5030	26900	25900	30000	30000
	14.45	2100	3150	3570	201	32	15300	17700	5240	5240	26700	25700	30000	30000
	16.00	1800	2270	3060	119	12	16000	18500	5810	5810	27700	26700	30000	30000

DRL..	i	n_{epk} [rpm]	η [%]	c_{TG} K [Nm/']	KF [Nm/']	KA [Nm/']	KAF [Nm/']	φ /R [']
K87 3	7.21	4378	96	169	156	411	411	7
	8.29	4500	96	169	156	411	411	7
	10.00	4500	96	169	156	411	411	7
	11.17	4500	96	169	156	411	411	7
	12.56	4378	96	198	181	640	640	6
	14.45	4500	96	198	181	640	640	6
	16.00	4500	96	169	156	411	411	6

Selected gear unit: KV87

- i = 12.56
- M_{amax} = 2000 Nm
- M_{apk} = 3000 Nm
- n_{epk} = 4378 rpm
- η = 0.96

Maximum motor speed

$$n_{max} = n_{a\,max} \times i$$

$$n_{max} = 171{,}67\,\frac{1}{min} \times 12{,}56$$

$$n_{max} = 2157\,\frac{1}{min}$$

Checking the selection critera

You find the selection criterion in the project planning procedure on page 40.

$M_{max} \leq M_{apk}$

2311.53 Nm ≤ 3000 Nm

$n_{max} \leq n_{epk}$

2157 rpm ≤ 4378 rpm

Conditions are fulfilled.

Checking gear unit KV87

A regular travel cycle is usually not known for storage/retrieval systems because the system covers variable distances within the overall distance. The actual velocity and speed is adjusted depending on the lifting times and travel distances, see also the travel diagram on page 51.

Mean output speed

$n_{amax} \approx 172$ rpm

cdf = 60%

$$n_{am} = n_{a\,max} \times \%ED$$

$$n_{am} = 172 \frac{1}{min} \times 0{,}6$$

$$n_{am} = 103 \frac{1}{min}$$

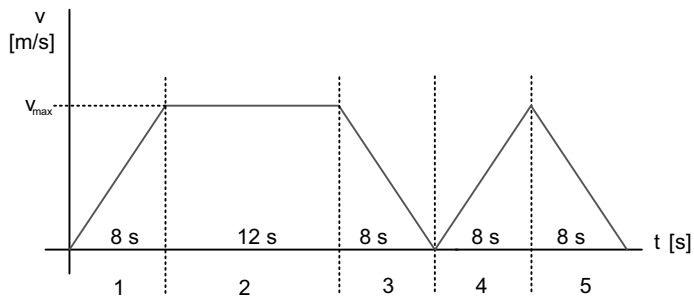
Selection criterion:

$$n_{am} \leq n_{ak}$$

$$103 \frac{1}{min} \leq 223 \frac{1}{min}$$

The condition is fulfilled.

Effective torque based on an adjusted travel profile



t_{ges} = 44 s

cdf = 60%

M_1 = 2311.53 Nm

M2 = 210.14 Nm

M3 = -1491.99 Nm

M_4 = 2311.53 Nm

M5 = -1491.99 Nm

$$n_1 = n_3 = n_4 = n_5 = \frac{n_{max}}{2}$$

$$n_1 = n_3 = n_4 = n_5 = \frac{172 \frac{1}{min}}{2}$$

$$n_1 = n_3 = n_4 = n_5 = 86 \frac{1}{min}$$

$n_2 = n_{max}$

$n_2 = 172$ rpm

$$M_{a\,eff} = \sqrt[8]{\frac{n_1 \times t_1 \times |M_1|^8 + \ldots + n_n \times t_n \times |M_n|^8}{n_1 \times t_1 + \ldots + n_n \times t_n}}$$

$$M_{a\,eff} = \sqrt[8]{\frac{86\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s} \times |2311{,}53|^8 + 172\,\frac{1}{\min} \times 12\,s \times \frac{1\,\min}{60\,s} \times |210{,}14|^8 + 172\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s} \times |-1491{,}99|^8 + 86\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s} \times |2311{,}53|^8 + 86\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s} \times |-1491{,}99|^8}{86\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s} + 172\,\frac{1}{\min} \times 12\,s \times \frac{1\,\min}{60\,s} + 86\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s} + 86\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s} + 86\,\frac{1}{\min} \times 8\,s \times \frac{1\,\min}{60\,s}}}$$

$$M_{a\,eff} = 1987{,}42\ Nm$$

Selection criterion:

$M_{a\,eff} \leq M_{a\,max}$

1984.11 Nm ≤ 2000 Nm

The condition is fulfilled.

Load torques in travel sections 1 to 3

Travel section 1

$$M_{e\,max1} = \frac{M_{max}}{i \times \eta_G}$$

$$M_{e\,max1} = \frac{2311{,}53\ Nm}{12{,}56 \times 0{,}96}$$

$$M_{e\,max1} = 191{,}71\ Nm$$

Travel section 2

$$M_{e\,max2} = \frac{M_{stat}}{i \times \eta_G}$$

$$M_{e\,max2} = \frac{210{,}14\ Nm}{12{,}56 \times 0{,}96}$$

$$M_{e\,max2} = 17{,}43\ Nm$$

Travel section 3

$$M_{e\,max3} = \frac{M_{max}}{i \times \eta_G}$$

$$M_{e\,max3} = \frac{-1491{,}99\ Nm}{12{,}56 \times 0{,}96}$$

$$M_{e\,max3} = -123{,}74\ Nm$$

Travel section 4 $M_{e\,max4} = M_{e\,max1}$

$M_{e\,max4} = 191.71$ Nm

Travel section 5 $M_{e\,max5} = M_{e\,max3}$

$M_{e\,max5} = -123.74$ Nm

Motor selection Preliminary determination of motor using torque M_{pk} and M_N.

$$M_N = \sqrt{\frac{t_1 \times M_1 + ... + t_n \times M_n}{t_{ges}}}$$

$$M_N = \sqrt{\frac{8\,s \times (191{,}71\ Nm)^2 + 12\,s \times (17{,}43\ Nm)^2 + 8\,s \times (-123{,}74\ Nm)^2 + 8\,s \times (191{,}71\ Nm)^2 + 8\,s \times (-123{,}74\ Nm)^2}{\frac{44\,s}{0{,}6}}}$$

$$M_N = 106{,}81\,Nm$$

M_{eff} = 106.81 Nm + dynamic share

n_N	Motor type	M_N Nm	I_N A	M_{pk} Dyn1 Nm	M_{pk} Dyn2 Nm	m kg	J_{Mot} 10^{-4} kgm²
2100	DRL71S4	2.6	2	5	8.5	8.6	4.9
	DRL71M4	3.8	2.7	7	14	10	7.1
	DRL80S	6.2	3.59	10	25	11.5	14.9
	DRL80M4	9.5	5	14	30	15.2	21.5
	DRL90L4	15	8.4	25	46	22.5	43.5
	DRL100L4	25	14	40	85	30	68
	DRL132S4	41	21.4	80	150	45.5	190
	DRL132MC4	52	28.8	130	200	65	340
	DRL160M4	85	44	165	280	93	450
	DRL160MC4	88	48	185	320	95	590
	DRL180S	110	55.3	210	380	122	900
	DRL180M4	130	64	250	430	143	1110
	DRL180L4	160	78	320	520	154	1300
	DRL180LC4	170	87	420	600	163	1680
	DRL200L	195	99	475	680	260	2360
	DRL225S4	235	119	520	770	295	2930
	DRL225MC4	265	142	770	1100	330	4330

Selected motor:

DRL180 M4

M_{pk} = 250 Nm / 430 Nm (D1 / D2)

J_{Mot} = 0.111 kgm²

J_{brake} = 0.023 kgm² (BE32)

Determining the inertia ratio "k"

$$J_{ext} = 91{,}2 \times m \times \left(\frac{v_{max}}{n_{max}}\right)^2$$

$$J_{ext} = 91{,}2 \times 17000\ kg \times \left(\frac{240\ \frac{m}{min} \times \frac{min}{60\ s}}{2157\ \frac{1}{min}}\right)^2$$

$$J_{ext} = 5{,}332\ kgm^2$$

J_{ext} is the mass moment of inertia in relation to the motor shaft.

$$k = \frac{J_{ext}}{J_{Mot} + J_{Bremse} + J_G}$$

$$k = \frac{5{,}332\ kgm^2}{0{,}111\ kgm^2 + 0{,}023\ kgm^2 + 0{,}0042\ kgm^2}$$

$$k = 38{,}6$$

Selection criterion:

k ≤ 50 (mass inertia ratio)

38.6 ≤ 50

The condition is fulfilled.

Intrinsic motor acceleration or deceleration in travel sections 1, 3, 4, 5

$$M_{Eigen} = \left(J_G + J_{Mot} + J_{Bremse}\right) \times \frac{n_{max}}{9{,}55 \times t}$$

$$M_{Eigen} = \left(0{,}0042\ kgm^2 + 0{,}111\ kgm^2 + 0{,}023\ kgm^2\right) \times \frac{2157\ \frac{1}{min}}{9{,}55 \times 8\ s}$$

$$M_{Eigen} = 3{,}9\ Nm$$

Maximum motor torques in travel sections 1 to 5

Travel sections 1, 4

$$M_{t1} = M_{e\,max1} + M_{Eigen}$$

$$M_{t1} = 191{,}71\ Nm + 3{,}9\ Nm$$

$$M_{t1} = 195{,}61\ Nm$$

Travel section 2

$$M_{t2} = M_{e\,max2}$$

$$M_{t2} = 17{,}43\ Nm$$

Travel sections 3, 5

$$M_{t3} = M_{e\,max3} + M_{Eigen}$$

$$M_{t3} = -123{,}74\ Nm + 3{,}9\ Nm$$

$$M_{t3} = -119{,}84\ Nm$$

Effective motor torque

$$M_{eff} = \sqrt{\frac{1}{t_z} \times \left(M_{t1}^2 \times t_1 + ... + M_{tn}^2 \times t_n \right)}$$

$$M_{eff} = \sqrt{\frac{1}{73{,}3\ s} \times \left((196\ Nm)^2 \times 8\ s + (17{,}5\ Nm)^2 \times 12\ s + (-120\ Nm)^2 \times 8\ s + (196\ Nm)^2 \times 8\ s + (-120\ Nm)^2 \times 8\ s \right)}$$

$$M_{eff} = 111{,}12\ Nm$$

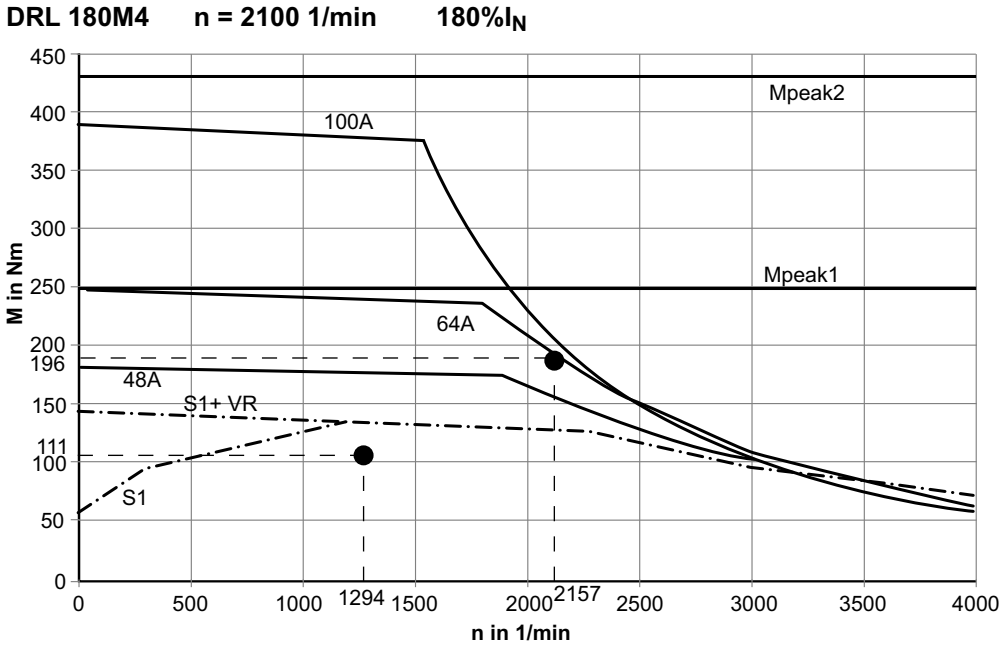
Effective motor speed

$$n_{eff} < n_{max} \times 0{,}6$$

$$n_{eff} < 2157\ \frac{1}{min} \times 0{,}6$$

$$n_{eff} < 1294\ \frac{1}{min}$$

Limit characteristic curves DRL – MOVIAXIS®, DC link voltage $V_{DC\ link}$ = 565 V, PWM = 8 kHz



n_{eff}	=	1294 rpm	M_{eff}	=	111.12 Nm
n_{max}	=	2157 rpm	M_{max}	=	195.61 Nm

Condition: The operating point (n_{eff}, M_{eff}) must lie below the S1 characteristic curve.
The maximum operating point (n_{max}, M_{max}) is required for selecting the inverter.

Inverter selection

You find information on inverter selection in the MOVIAXIS® and MOVIDRIVE® system manuals.

Selecting the braking resistor

Peak braking power in travel sections 3 and 5

$$P_{Br_pk} = \frac{M_{tn} \times n_{tn} \times \eta_L}{9550}$$

$$P_{Br_pk} = \frac{198\ Nm \times 2157\ \frac{1}{\min} \times 0{,}9}{9550}$$

$$P_{Br_pk} = 40\ kW$$

Mean braking power in travel sections 3 and 5

$$P_{Br} = \frac{P_{Br_pk}}{2}$$

$$P_{Br} = \frac{40\ kW}{2}$$

$$P_{Br} = 20\ kW$$

Effective braking power in travel sections 3 and 5

$$P_{Br_eff} = \frac{P_{Br} \times (t_3 + t_5)}{t_z}$$

$$P_{Br_eff} = \frac{20\ kW \times (8\ s + 8\ s)}{44\ s}$$

$$P_{Br_eff} = 7{,}3\ kW$$

The selection of the braking resistor depends, among other factors, on which braking resistor may be connected to the respective inverter. For more information, refer to the inverters' system manuals MOVIAXIS® and MOVIDRIVE®.

You can also determine braking resistors via the "SEW Workbench".

Thermal emergency load of the brake (EMERGENCY STOP)

$$W_B = \frac{M_B}{M_B + M_L \times \eta_L} \times \frac{(J_{Mot} + J_B + J_{ext} \times \eta_L) \times n_{\max}^2}{182{,}5}$$

$$W_B = \frac{M_B}{M_B + 17{,}61\ Nm \times 0{,}9} \times \frac{\left(0{,}111\ kgm^2 + 0{,}023\ kgm^2 + 5{,}332\ kgm^2 \times 0{,}9\right) \times \left(2157\ \frac{1}{\min}\right)^2}{182{,}5}$$

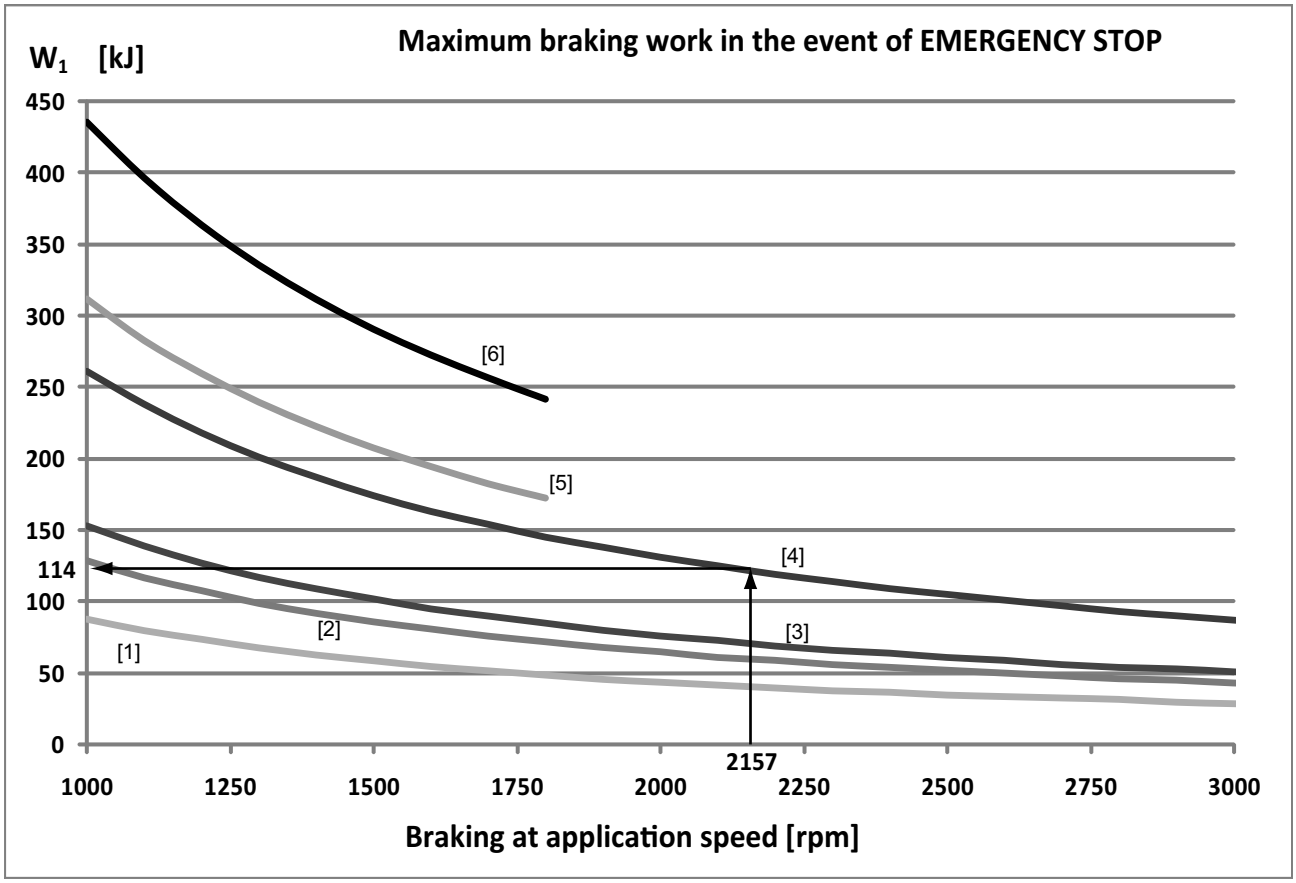
$$W_B = \frac{M_B}{M_B + 15{,}85\ Nm} \times 125756\ J$$

$$W_B = \frac{M_B}{M_B + 15{,}85\ Nm} \times 125756\ J$$

$$W_B = \frac{150\ Nm}{150\ Nm + 15{,}85\ Nm} \times 125756\ J$$

$$W_B = 113738\ J$$

The brake can be selected in the following diagram by means of the value 113.74 kJ:



[1]	BE11	**[4]**	**BE32**
[2]	BE20	[5]	BE120
[3]	BE30	[6]	BE122
n_{max}	= 2157 rpm	W_B	= 113.74 kJ

Selected brake: BE32

Assigned braking torque: 150 Nm

Selected drive

KV87 DRL180M4 BE32

i = 12.56

M_B = 150 Nm

Checking the gear unit's braking torque

$$M_{a\,Bremse} \approx M_{Bremse} \times i$$
$$M_{a\,Bremse} \approx 150\ Nm \times 12{,}56$$
$$M_{a\,Bremse} \approx 1884\ Nm$$

Criterion:

$M_{a\ brake} < M_{amax}$

1884 Nm < 2000 Nm

The condition is fulfilled.