4 Project Planning for Gear Units

4.1 Efficiency of gear units

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 factor is especially pronounced in the case of helical-worm gear units.

R, F, K gear units

The efficiency of helical, parallel shaft and helical-bevel gear units varies with the number of gear stages, between 94 % (3-stage) and 98 % (1-stage).

S gear units

The gearing of helical-worm gear units produces a high proportion of sliding friction. As a result, these gear units may have higher gearing losses than R, F or K gear units and thus be less efficient.

The efficiency depends on the following factors:

- Gear ratio of the helical-worm gear stage
- Input speed
- Gear unit temperature

SEW-helical-worm gear units are helical gear/worm combinations that are significantly more efficient than straightforward worm gear units. The efficiency may reach $\eta < 0.5$ if the helical-worm gear stage has a very high gear ratio.

Self-locking

Retrodriving torques on helical-worm gear units produce an efficiency of $\eta\Pi = 2 -1\eta'$, which is significantly less favorable than the forward efficiency η. The helical-worm gear unit is self-locking if the forward efficiency $\eta \leq 0.5$. A few SEW helical-worm gear units with the largest gear ratio are statically self-locking but not dynamically self-braking. Contact SEW-EURODRIVE if you wish to make technical use of the braking effect of self-locking characteristics.

Run-in phase

The tooth flanks of new helical-worm gear units are not completely smooth. That fact makes for a greater friction angle and less efficiency than during later operation. This effect becomes more apparent the greater the gear ratio. Subtract the following values from the listed efficiency during the run-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 %
4 start	-	-
5 start	ca. 6 ... 25	ca. 3 %
6 start	ca. 7 ... 25	ca. 2 %

The run-in phase usually lasts 24 hours. The helical-worm gear units achieve their listed rated efficiency values when:

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

Churning losses

In certain gear unit mounting positions (→ Sec. "Mounting Positions and Important Order Information") the first reduction stage is completely immersed in the lubricant. With larger gear unit sizes and high circumferential velocities of the input stage, this gives rise to churning losses constituting a factor which cannot be ignored. Contact SEW-EURODRIVE if you wish to use gear units of this type.

If possible, use mounting position M1 for R, K and S gear units to keep the churning losses low.

4.2 Service Factor

Determining the service factor

The effect of the driven machine on the gear unit is taken into account to a sufficient level of accuracy using the service factor f_B. The service factor is determined according to the daily operating time and the starting frequency Z. Three load classifications are considered depending on the mass acceleration factor. You can read off the service factor applicable to your application in Figure 3 . The service factor determined using this diagram must be less than or equal to the service factor as given in the selection tables.

$$\mathbf{M_a \cdot f_b \leq M_{a\,max}}$$

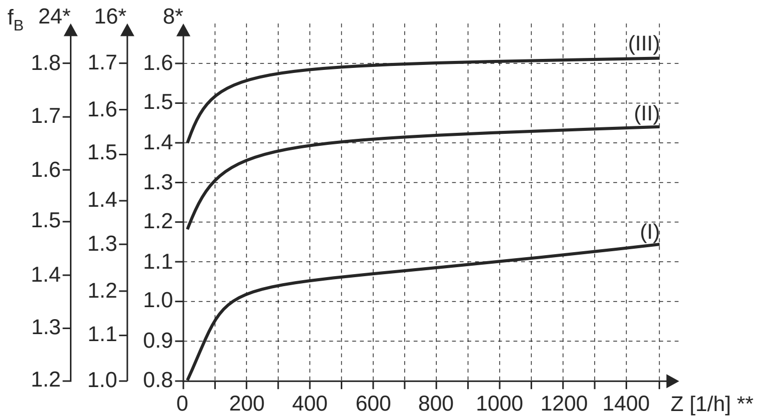

Figure 3: Service factor f_B

* Daily operating time in hours/day
** Starting frequency Z: The cycles include all starting and braking procedures as well as changeovers from low to high speed and vice versa.

Load classification

Three load classifications are differentiated:

(I) Uniform, permitted mass acceleration factor ≤ 0.2

(II) Moderate shock load, permitted mass acceleration factor ≤ 3

(III) Heavy shock load, permitted mass acceleration factor ≤ 10

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Mass acceleration factor

The mass acceleration factor is calculated as follows:

$$\textbf{Mass acceleration factor} = \frac{\textbf{All external mass moments of inertia}}{\textbf{Mass moment of inertia on the motor end}}$$

"All external mass moments of inertia" are the mass moments of inertia of the driven machine and the gear unit, scaled down to the motor speed. The calculation for scaling down to motor speed is performed using the following formula:

$$J_X = J \times \left(\frac{n}{n_M}\right)^2$$

J_X = Reduced mass moment of inertia on the motor shaft
J = Mass moment of inertia referenced to the output speed of the gear unit
n = Output speed of the gear unit
n_M = Motor speed

"Mass moment of inertia at the motor end" is the mass moment of inertia of the motor and, if installed, the brake and the flywheel fan (Z fan).

Service factors f_B > 1.8 may occur with large mass acceleration factors (> 10), higlevels of backlash in the transmission elements or large overhung loads. Contact SEW-EURODRIVE in such cases.

Servicefactor: SEW f_B

The method for determining the maximum permitted continuous torque $M_{a\ max}$ and using this value to derive the service factor $f_B = M_{a\ max}/M_a$ is not defined in a standard and varies greatly from manufacturer to manufacturer. Even at a SEW service factor of $f_B = 1$, the gear units afford an extremely high level of safety and reliability in the fatigue strength range (exception: wearing of the worm wheel in helical-worm gear units). Under certain circumstances, the service factor may not be comparable with the information given by other gear unit manufacturers. If in doubt, please contact SEW-EURODRIVE to find out more detailed information for your specific drive.

Example

Mass acceleration factor 2.5 (load classification II), 14 hours/day operating time (read off at 16 h/d) and 300 cycles/hour result in a service factor $f_B = 1.51$ according to Figure 3 .

Helical-worm gear units

For helical-worm gear units, two additional service factors will have to be taken into consideration besides service factor f_B derived from Figure 3 . These are:

- f_{B1} = Service factor from the ambient temperature
- f_{B2} = Service factor from the cyclic duration factor

The additional service factors f_{B1} and f_{B2} can be determined by referring to the diagrams in Figure 4 . The load classification is taken into consideration in f_{B1} in the same way as in f_B.

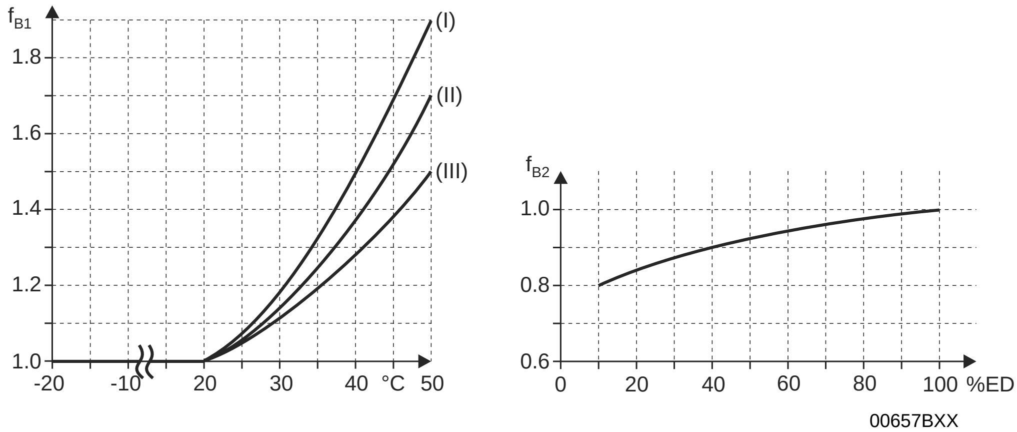

Figure 4: Additional service factors f_{B1} and f_{B2}

$$\textbf{cdf (\%)} = \frac{\textbf{Time under load in min/h}}{\textbf{60}} \bullet \textbf{100}$$

Contact SEW-EURODRIVE in case of temperatures below -20 °C ($\rightarrow f_{B1}$).

The total service factor for helical-worm gear units is calculated as follows:

$$\mathbf{f_{Btot} = f_B \bullet f_{B1} \bullet f_{B2}}$$

Example

The gear unit with the service factor f_B = 1.51 in the previous example is to be a helical-worm gearmotor.

Ambient temperature ϑ = 40°C $\rightarrow$ f_{B1} = 1.38 (read off at load classification II)

Time under load = 40 min/h $\rightarrow$cdf = 66.67 % $\rightarrow$ f_{B2} = 0.95

The total service factor is $f_{Btot} = 1.51 \times 1.38 \times 0.95 = 1.98$

4.3 Overhung loads and axial forces

Determining overhung load

When determining the resulting overhung load, the type of transmission element mounted on the shaft end must be considered. The following transmission element factors f_Z also 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	Pre-tensioning influence
Flat belt pulleys	2.50	Pre-tensioning influence
Toothed belt pulleys	2.50	Pre-tensioning influence

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

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

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

Permitted overhung load

The basis for determining the permitted overhung loads is the computation of the rated service life L_{H10} of the anti-friction 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. Contact SEW-EURODRIVE in case of other versions.

The data refer to the radial force acting midway on the shaft end (with right-angle gear units on the A-side output). Worst case conditions have been assumed for the force application angle α and the direction of rotation.

- Only 50 % of the F_{Ra} value specified in the selection tables is permitted in mounting position M1 with wall attachment on the front face for K and S gear units.
- Helical-bevel gear units K167 and K187 in mounting positions M1 to M4: A maximum of 50 % of the overhung load F_{Ra} 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 gear units (R..F): A maximum of 50 % of the overhung load F_{Ra} specified in the selection tables for torque transmission via flange mounting are permitted.

Higher permitted overhung loads

Higher output shaft loads are permitted if heavy duty bearings are installed, especially with R, F and K gear units. Exactly considering the force application angle α and the direction of rotation makes it possible to achieve a higher overhung load. Contact SEW-EURODRIVE in such cases.

Definition of force application

Force application is defined according to the following figure:

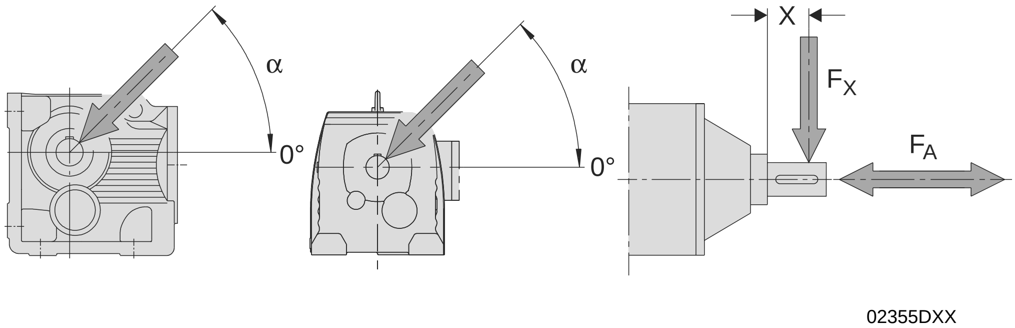

Figure 5: Definition of force application point

F_X = Permitted overhung load at point x [N]

F_A = Permitted axial force [N]

Permitted axial forces

If there is no overhung load, then an axial force F_A (tension or compression) amounting to the following percentages of the overhung load given in the selection tables is permitted.

40 % on the input side

- for input shaft assemblies except for AD7 and AD8

50 % on the output side

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

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

Overhung load conversion on the output side for off-center force application

Please contact SEW-EURODRIVE in case of off-center force application.

Overhung load conversion on the output side for off-center force application

The permitted overhung loads given in the selection tables must be calculated using the following formulae in the event of force application not in the center of the shaft end. The smaller of the two values F_{xL} (according to bearing service life) and F_{xW} (according to shaft strength) is the permitted value for the overhung load at point x. Note that the calculations apply to $M_{a\ max}$.

F_{XL} according to bearing service life

$$F_{xL} = F_{Ra} \bullet \frac{a}{b + x} \text{ [N]}$$

F_{xW} from the shaft strength

$$F_{xW} = \frac{c}{f + x} \text{ [N]}$$

F_{Ra}	= Permitted overhung load (x = l/2) for foot-mounted gear units according to the selection tables in [N]
x	= Distance from the shaft shoulder to the force application point in [mm]
a, b, f	= Gear unit constant for overhung load conversion [mm]
c	= Gear unit constant for overhung load conversion [mm]

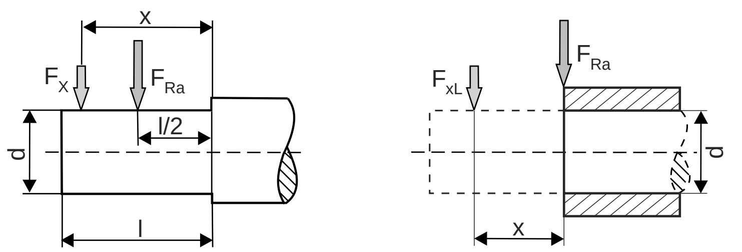

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Figure 6: Overhung load F_x for off-center force application

Gear unit constants for overhung load conversion

Gear unit type	a [mm]	b [mm]	c [Nmm]	f [mm]	d [mm]	l [mm]
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	2.51×10^5	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	1.19×10^6	0	60	120
R107	285.5	215.5	2.06×10^6	0	70	140
R137	343.5	258.5	6.14×10^6	30	90	170
R147	402	297	8.65×10^6	33	110	210
R167	450	345	1.26×10^7	0	120	210
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
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	1.78×10^5	0	30	60
F57	170.7	135.7	5.49×10^5	32	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	1.19×10^6	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	1.41×10^5	0	25	50
K47	153.5	123.5	1.78×10^5	0	30	60
K57	169.7	134.7	6.8×10^5	31	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	2.8×10^6	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
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.

4.4 RM gear units

project planning You must take account of the higher overhung and axial loads when planning projects with RM helical gear units with extended bearing hub. Observe the following project planning procedure:

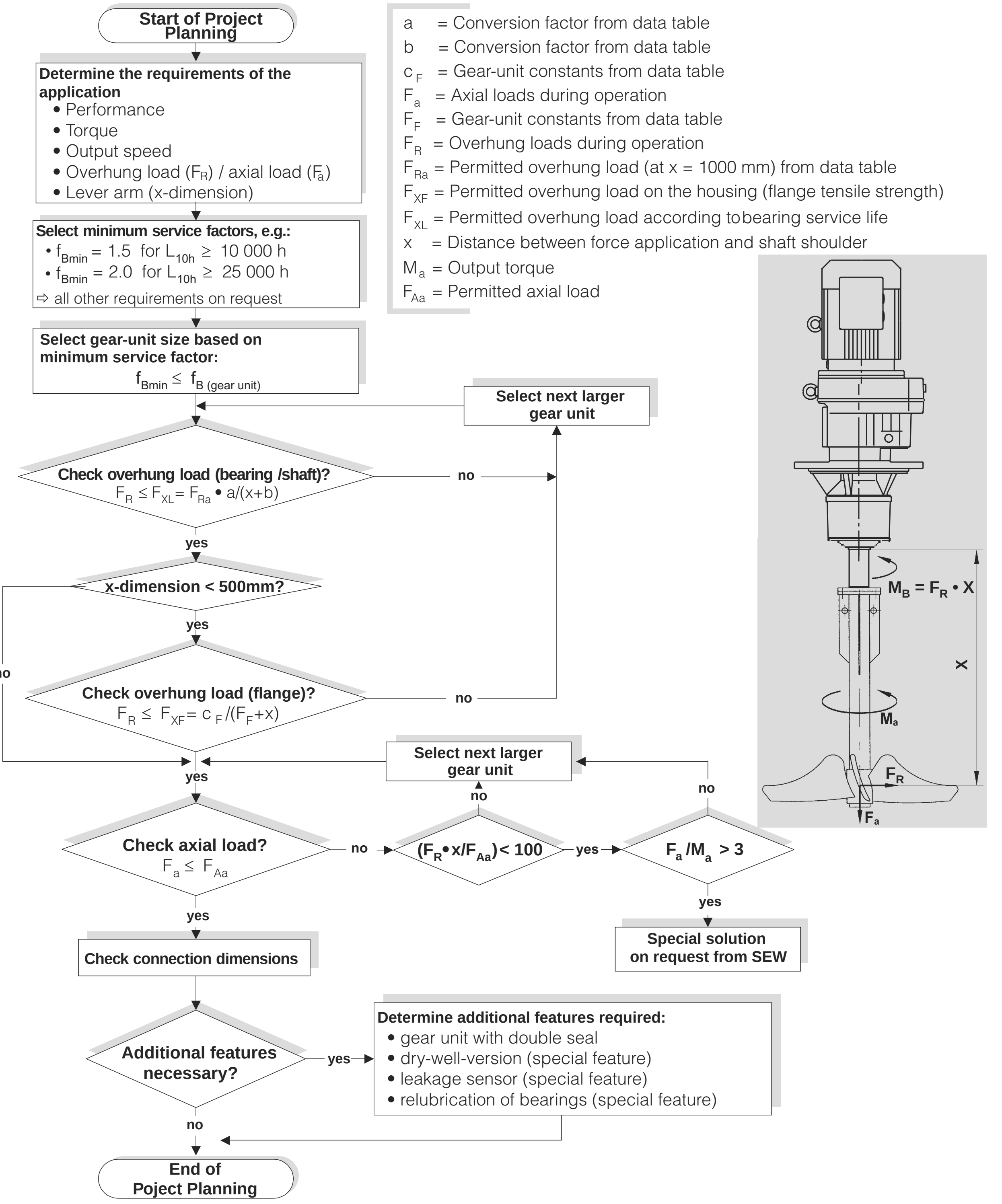

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Figure 7: Project planning for RM gear units

Permitted overhung loads and axial forces

The permitted overhung loads F_{Ra} and axial loads F_{Aa} are specified for various service factors f_B and nominal bearing service life L_{H10}.

f_{Bmin} = 1.5; L_{10h} = 10,000 h

			Output speed n_a [1/min]							
			< 16	16-25	26-40	41-60	61-100	101-160	161-250	251-400
RM57	F_{Ra}	[N]	400	400	400	400	400	405	410	415
	F_{Aa}	[N]	18800	15000	11500	9700	7100	5650	4450	3800
RM67	F_{Ra}	[N]	575	575	575	580	575	585	590	600
	F_{Aa}	[N]	19000	18900	15300	11900	9210	7470	5870	5050
RM77	F_{Ra}	[N]	1200	1200	1200	1200	1200	1210	1210	1220
	F_{Aa}	[N]	22000	22000	19400	15100	11400	9220	7200	6710
RM87	F_{Ra}	[N]	1970	1970	1970	1970	1980	1990	2000	2010
	F_{Aa}	[N]	30000	30000	23600	18000	14300	11000	8940	8030
RM97	F_{Ra}	[N]	2980	2980	2980	2990	3010	3050	3060	3080
	F_{Aa}	[N]	40000	36100	27300	20300	15900	12600	9640	7810
RM107	F_{Ra}	[N]	4230	4230	4230	4230	4230	4230	3580	3830
	F_{Aa}	[N]	48000	41000	30300	23000	18000	13100	9550	9030
RM137	F_{Ra}	[N]	8710	8710	8710	8710	7220	5060	3980	6750
	F_{Aa}	[N]	70000	70000	70000	57600	46900	44000	35600	32400
RM147	F_{Ra}	[N]	11100	11100	11100	11100	11100	10600	8640	10800
	F_{Aa}	[N]	70000	70000	69700	58400	45600	38000	32800	30800
RM167	F_{Ra}	[N]	14600	14600	14600	14600	14600	14700	-	-
	F_{Aa}	[N]	70000	70000	70000	60300	45300	36900	-	-

f_{Bmin} = 2.0; L_{10h} = 25,000 h

			Output speed n_a [1/min]							
			< 16	16-25	26-40	41-60	61-100	101-160	161-250	251-400
RM57	F_{Ra}	[N]	410	410	410	410	410	415	415	420
	F_{Aa}	[N]	12100	9600	7350	6050	4300	3350	2600	2200
RM67	F_{Ra}	[N]	590	590	590	595	590	595	600	605
	F_{Aa}	[N]	15800	12000	9580	7330	5580	4460	3460	2930
RM77	F_{Ra}	[N]	1210	1210	1210	1210	1210	1220	1220	1220
	F_{Aa}	[N]	20000	15400	11900	9070	6670	5280	4010	3700
RM87	F_{Ra}	[N]	2000	2000	2000	2000	2000	1720	1690	1710
	F_{Aa}	[N]	24600	19200	14300	10600	8190	6100	5490	4860
RM97	F_{Ra}	[N]	3040	3040	3040	3050	3070	3080	2540	2430
	F_{Aa}	[N]	28400	22000	16200	11600	8850	6840	5830	4760
RM107	F_{Ra}	[N]	4330	4330	4330	4330	4330	3350	2810	2990
	F_{Aa}	[N]	32300	24800	17800	13000	9780	8170	5950	5620
RM137	F_{Ra}	[N]	8850	8850	8850	8830	5660	4020	3200	5240
	F_{Aa}	[N]	70000	59900	48000	37900	33800	31700	25600	23300
RM147	F_{Ra}	[N]	11400	11400	11400	11400	11400	8320	6850	8440
	F_{Aa}	[N]	70000	60600	45900	39900	33500	27900	24100	22600
RM167	F_{Ra}	[N]	15100	15100	15100	15100	15100	13100	-	-
	F_{Aa}	[N]	70000	63500	51600	37800	26800	23600	-	-

Conversion factors and gear unit constants

The following conversion factors and gear unit constants apply to calculating the permitted overhung load F_{xL} at point x ≠ 1000 mm for RM gearmotors:

Gear unit type	a	b	c_F (f_B = 1.5)	c_F (f_B = 2.0)	F_F
RM57	1047	47	1220600	1260400	277
RM67	1047	47	2047600	2100000	297.5
RM77	1050	50	2512800	2574700	340.5
RM87	1056.5	56.5	4917800	5029000	414
RM97	1061	61	10911600	11124100	481
RM107	1069	69	15367000	15652000	554.5
RM137	1088	88	25291700	25993600	650
RM147	1091	91	30038700	31173900	756
RM167	1089.5	89.5	42096100	43654300	869

Additional weights of RM gear units

Type	Additional weight in addition to RF, related to the smallest RF flange Δm [kg]
RM57	12.0
RM67	15.8
RM77	25.0
RM87	29.7
RM97	51.3
RM107	88.0
RM137	111.1
RM147	167.4
RM167	195.4