4 Project Planning for Gear Units

4.1 Efficiency of gear units

The efficiency of the 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 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 94 % (3-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 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 or Spiroplan® stage
- Input speed
- Gear unit temperature

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 or Spiroplan® stage has a very high ratio step.

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 $\eta \leq 0.5$. A few helical-worm gear units with the largest gear ratio are statically self-locking. Some Spiroplan® gear units are also dynamically self-locking. 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 and Spiroplan® gear units are not yet 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		Spiroplan®	
	i range	**η reduction**	**i range**	**η reduction**
1 start	ca. 50 ... 280	ca. 12 %	ca. 40 ... 75	ca. 15 %
2 start	ca. 20 ... 75	ca. 6 %	ca. 20 ... 30	ca. 10 %
3 start	ca. 20 ... 90	ca. 3 %	ca. 15	ca. 8 %
4 start	-	-	ca. 10	ca. 8 %
5 start	ca. 6 ... 25	ca. 3 %	ca. 8	ca. 5 %
6 start	ca. 7 ... 25	ca. 2 %	-	-

The run-in phase usually lasts 24 hours. Helical-worm and Spiroplan® 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-EURO-DRIVE 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.
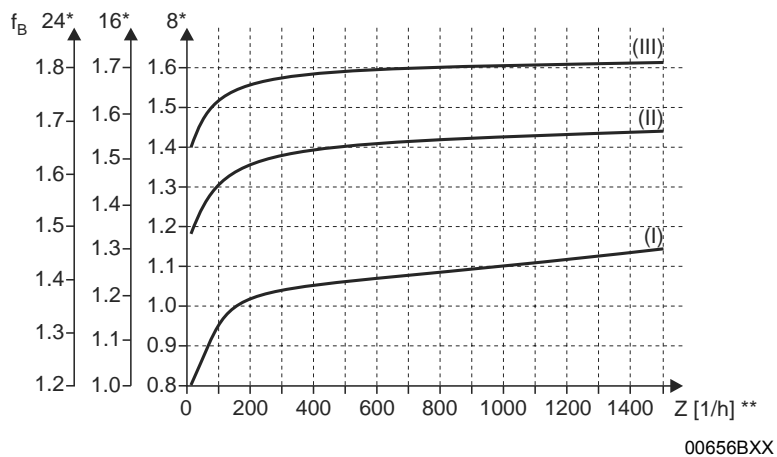

Figure 3: Service factor f_B

* 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

*Mass acceleration
factor*

The mass acceleration factor is calculated as follows:

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

"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), high levels of backlash in the transmission elements or large overhung loads. Contact SEW-EURODRIVE in such cases.

Service factor: SEW f_B

The method for determining the maximum permitted continuous torque M_{amax} and using this value to derive the service factor $f_B = M_{amax}/M_a$ 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 Figure 3 result in a service factor $f_B = 1.51$. According to the selection tables, the selected gearmotor must have an SEW f_B value of 1.51 or greater.

4

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 inFigure 4 . The load classification is taken into consideration in f_{B1} in the same way as in f_B.

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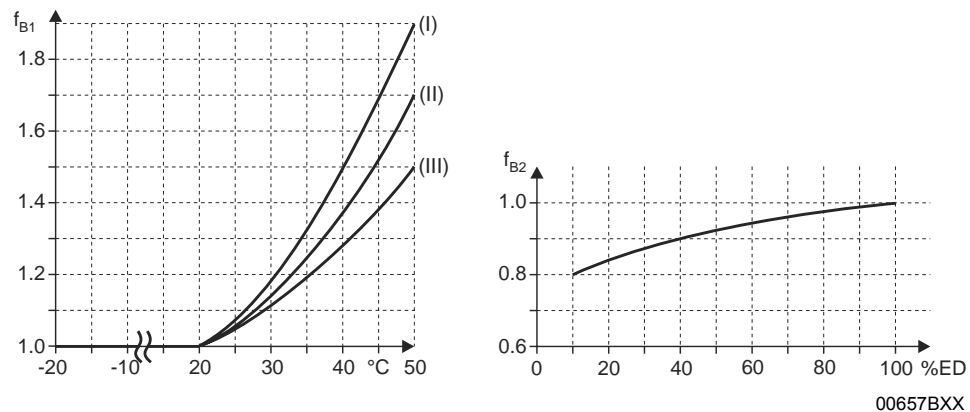
Figure 4: Additional service factors f_{B1} and f_{B2}

$$ED\ (\%) = \frac{\text{Time under load in min/h}}{60} \bullet 1$$

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:

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

Example

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

Ambient temperature $\vartheta = 40$ °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 $f_{Btot} = 1.51 \bullet 1.38 \bullet 0.95 = 1.98$

According to the selection tables, the selected helical-worm gearmotor must have an SEW f_B service factor of 1.98 or greater.

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	1.50	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_{10h} 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 for gearmotors. Contact SEW-EURO-DRIVE 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 gearmotors 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 gearmotors (R..F): A maximum of 50 % of the overhung load F_{Ra} 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. 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

Force application is defined according to the following diagram:
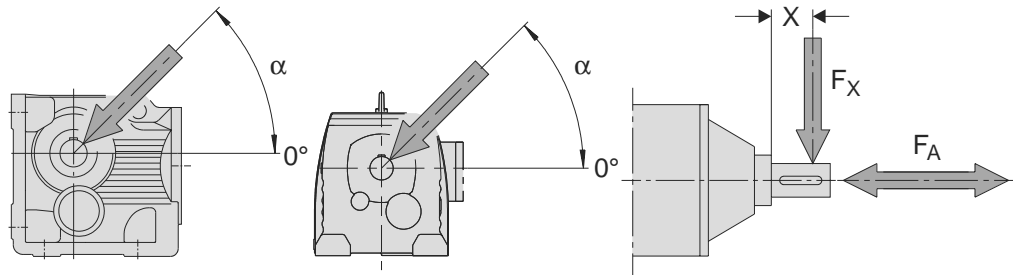
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Figure 5: Definition of force application

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 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

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 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

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

F_{xW} from the shaft strength

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

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 constants for overhung load conversion [mm]

c = Gear unit constant for overhung load conversion [Nmm]
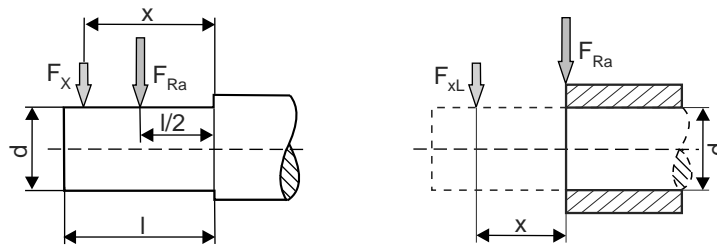
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Figure 6: Overhung load F_X for off-center force application

Gear unit con-stants for overhung load conversion

Gear unit type	a [mm]	b [mm]	c [Nmm]	f [mm]	d [mm]	l [mm]
RX57	43.5	23.5	$1.51 \cdot 10^5$	34.2	20	40
RX67	52.5	27.5	$2.42 \cdot 10^5$	39.7	25	50
RX77	60.5	30.5	$1.95 \cdot 10^5$	0	30	60
RX87	73.5	33.5	$7.69 \cdot 10^5$	48.9	40	80
RX97	86.5	36.5	$1.43 \cdot 10^6$	53.9	50	100
RX107	102.5	42.5	$2.47 \cdot 10^6$	62.3	60	120
R07	72.0	52.0	$4.67 \cdot 10^4$	11	20	40
R17	88.5	68.5	$6.527 \cdot 10^4$	17	20	40
R27	106.5	81.5	$1.56 \cdot 10^5$	11.8	25	50
R37	118	93	$1.24 \cdot 10^5$	0	25	50
R47	137	107	$2.44 \cdot 10^5$	15	30	60
R57	147.5	112.5	$3.77 \cdot 10^5$	18	35	70
R67	168.5	133.5	$2.51 \cdot 10^5$	0	35	70
R77	173.7	133.7	$3.97 \cdot 10^5$	0	40	80
R87	216.7	166.7	$8.47 \cdot 10^5$	0	50	100
R97	255.5	195.5	$1.19 \cdot 10^6$	0	60	120
R107	285.5	215.5	$2.06 \cdot 10^6$	0	70	140
R137	343.5	258.5	$6.14 \cdot 10^6$	30	90	170
R147	402	297	$8.65 \cdot 10^6$	33	110	210
R167	450	345	$1.26 \cdot 10^7$	0	120	210
F27	109.5	84.5	$1.13 \cdot 10^5$	0	25	50
F37	123.5	98.5	$1.07 \cdot 10^5$	0	25	50
F47	153.5	123.5	$1.78 \cdot 10^5$	0	30	60
F57	170.7	135.7	$5.49 \cdot 10^5$	32	35	70
F67	181.3	141.3	$4.12 \cdot 10^5$	0	40	80
F77	215.8	165.8	$7.87 \cdot 10^5$	0	50	100
F87	263	203	$1.19 \cdot 10^6$	0	60	120
F97	350	280	$2.09 \cdot 10^6$	0	70	140
F107	373.5	288.5	$4.23 \cdot 10^6$	0	90	170
F127	442.5	337.5	$9.45 \cdot 10^6$	0	110	210
F157	512	407	$1.05 \cdot 10^7$	0	120	210
K37	123.5	98.5	$1.41 \cdot 10^5$	0	25	50
K47	153.5	123.5	$1.78 \cdot 10^5$	0	30	60
K57	169.7	134.7	$6.8 \cdot 10^5$	31	35	70
K67	181.3	141.3	$4.12 \cdot 10^5$	0	40	80
K77	215.8	165.8	$7.69 \cdot 10^5$	0	50	100
K87	252	192	$1.64 \cdot 10^6$	0	60	120
K97	319	249	$2.8 \cdot 10^6$	0	70	140
K107	373.5	288.5	$5.53 \cdot 10^6$	0	90	170
K127	443.5	338.5	$8.31 \cdot 10^6$	0	110	210
K157	509	404	$1.18 \cdot 10^7$	0	120	210
K167	621.5	496.5	$1.88 \cdot 10^7$	0	160	250
K187	720.5	560.5	$3.04 \cdot 10^7$	0	190	320
W10	84.8	64.8	$3.6 \cdot 10^4$	0	16	40
W20	98.5	78.5	$4.4 \cdot 10^4$	0	20	40
W30	109.5	89.5	$6.0 \cdot 10^4$	0	20	40
S37	118.5	98.5	$6.0 \cdot 10^4$	0	20	40
S47	130	105	$1.33 \cdot 10^5$	0	25	50
S57	150	120	$2.14 \cdot 10^5$	0	30	60
S67	184	149	$3.04 \cdot 10^5$	0	35	70
S77	224	179	$5.26 \cdot 10^5$	0	45	90
S87	281.5	221.5	$1.68 \cdot 10^6$	0	60	120
S97	326.3	256.3	$2.54 \cdot 10^6$	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 loads and axial forces when planning projects with RM helical gearmotors with extended bearing housing. Observe the following project planning procedure:

a = Conversion factor from data table
b = Conversion factor from data table
c_F = Gear-unit constants from data table
F_a = Axial loads during operation
F_F = Gear-unit constants from data table
F_R = Overhung loads during operation
F_{Ra} = Permitted overhung load (at x = 1000 mm) from data table
F_{XF} = Permitted overhung load on the housing (flange tensile strength)
F_{XL} = Permitted overhung load according to bearing service life
x = Distance between force application and shaft shoulder
M_a = Output torque
F_{Aa} = Permitted axial load

Start of Project Planning

Determine the requirements of the application
• Performance
• Torque
• Output speed
• Overhung load (F_R) / axial load (F_a)
• Lever arm (x-dimension)

Select minimum service factors, e.g.:
• f_{Bmin} = 1.5 for $L_{10h} \geq$ 10 000 h
• f_{Bmin} = 2.0 for $L_{10h} \geq$ 25 000 h
⇨ all other requirements on request

Select gear-unit size based on minimum service factor:
$$f_{Bmin} \leq f_{B \, (gear \, unit)}$$

Select next larger gear unit

Check overhung load (bearing /shaft)?
$F_R \leq F_{XL} = F_{Ra} \cdot a/(x+b)$ no

yes

x-dimension < 500mm?   yes

no

Check overhung load (flange)?
$F_R \leq F_{XF} = c_F /(F_F+x)$ no

yes

Select next larger gear unit

Check axial load?
$F_a \leq F_{Aa}$ no $(F_R \cdot x/F_{Aa}) < 100$ yes $F_a /M_a > 3$

yes   no   no   yes

Special solution on request from SEW

Check connection dimensions

Additional features necessary?   yes

Determine additional features required:
• gear unit with double seal
• dry-well-version (special feature)
• leakage sensor (special feature)
• relubrication of bearings (special feature)

no

End of Poject Planning

$M_B = F_R \cdot X$

x

M_a

F_R

F_a

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Figure 7: Project planning for RM gear units

Permitted over-hung loads and axial forces

The permitted overhung loads F_{Ra} and axial forces F_{Aa} are specified for various service factors f_B and nominal bearing service life L_{10h}.

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

		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	-	-

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

		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 $x \neq 1000$ 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

4.5 Drives for overhead trolley systems

Special gearmotors with an integrated coupling are required for operating overhead trolley systems. SEW-EURODRIVE offers a range of drives for overhead trolley systems. You will find detailed information on this topic in the "Drives for Overhead Trolley Systems" catalog.
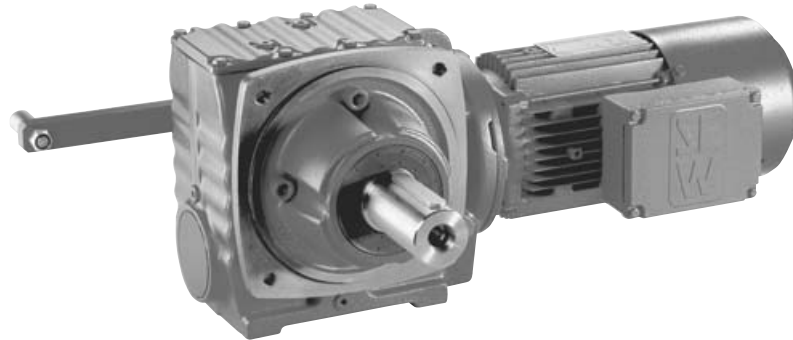
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Figure 8: Drive for overhead trolley systems

Type designation

Drives for overhead trolley systems have the following unit designation:

Type	Description
HW..	Overhead trolley drive based on Spiroplan® gear unit
HS..	Overhead trolley drive based on helical-worm gear unit
HK..	Overhead trolley drive based on helical-bevel gear unit

Division into two groups

Drives for overhead trolley systems are divided into two groups:

Group	Drives
Drives for overhead trolley systems according to VDI 3643 directive (C1 standard)	HW30 HS40 (up to motor size DT80)
Drives for heavy duty overhead trolley systems	HS41 / HS50 / HS60 HK30 / HK40 / HK50 / HK60

Technical data

The following technical data apply to overhead trolley drives:

Type	$M_{a\ max}$ [Nm]	F_{Ra} [Nm]	Ratios i	Shaft end d [mm]	l [mm]
HW30	70	5600	8.2 - 75	20 25	35 35
HS40	120	6500	7.28 - 201	20 25	35 35
HS41	185	10000	7.28 - 201	25	35
HS50	300	15000	7.28 - 201	30 35	60 70
HS60	600	25000	7.56 - 217.41	45	90
HK30	200	10000	13.1 - 106.38	25	35
HK40	400	18500	12.2 - 131.87	30 35	60 70
HK50	600	25000	13.25 - 145.14	45	90
HK60	820	40000	13.22 - 144.79	55	110