5 Project Planning for Gear Units

5.1 Efficiency of gear units

The efficiency of the gear unit is mainly determined by the gearing and bearing friction. Note that the starting efficiency of a gear unit is always less than its efficiency at operating speed.

The efficiency of MC.. helical and bevel-helical gear units varies depending on the number of gear stages.

Based on nominal power, the efficiency η is roughly:

- MC2P: 0.97
- MC3P: 0.955
- MC2R: 0.97
- MC3R: 0.955

5.2 Service factor F_S, peak factor F_F

Service factor F_S

The service factor takes into account the load impacts generated by the driving motor and the driven machine.

Recommended values in respect to

- field of application
- driven machine
- operating period / day

are given in the following table.

These tables are valid for **electric motors** used as driving machine.

For other types of driving machines, the following correction values apply:

- Combustion engines with four or more cylinders: F_S (selection table) + 0.25
- Combustion engines with one or three cylinders: F_S (selection table) + 0.5

Field of application/industry	Driven machine	Service factor operating period /day		
		< 3 h	3-10 h	> 10 h
Agitators and mixers	Agitators for liquids	1.00	1.25	1.50
	Agitators for liquids (variable density)	1.20	1.50	1.65
	Agitators for solids (non-uniform material)	1.40	1.60	1.70
	Agitators for solids (uniform material)	-	1.35	1.40
	Concrete mixers	-	1.50	1.50
Cableways	Material ropeways	-	1.40	1.50
	Aerial tramways	[1]	[1]	[1]
	Surface lifts	[1]	[1]	[1]
	Continuous aerial tramways	[1]	[1]	[1]
	Funicular railway	[1]	[1]	[1]
Conveyors	Bucket elevators	-	1.40	1.50
	Hoists - other	-	1.50	1.80
	Belt conveyors ≤ 100 kW	1.15	1.25	1.40
	Belt conveyors > 100 kW	1.15	1.30	1.50
	Apron feeders	-	1.25	1.50
	Screw feeders	1.15	1.25	1.50
	Shakers, reciprocating	1.55	1.75	2.00
	Escalators	1.55	1.25	1.50
	Passenger lifts	[1]	[1]	[1]
Compressors	Reciprocating	-	1.80	1.90
	Centrifugal compressor	-	1.40	1.50
	screw-type	-	1.50	1.75
Cranes and hoists	Cranes and hoists	[1]	[2]	[2]
Energy	Frequency converters	-	1.80	2.00
	Water wheels (low speed)	-	-	1.70
	Water turbines	-	-	[1]
Fans	Heat exchangers	1.50	1.50	1.50
	Dry cooling towers	-	-	2.00
	Wet cooling towers	2.00	2.00	2.00
	Blowers (axial and radial)	1.50	1.50	1.50
Food industry	Crushers and mills	-	-	1.75
	Beet slicer	-	1.25	1.50
	Drying Drums	-	1.25	1.50
Metal mills	Winders	-	1.60	1.75
	Slitters	1.55	1.75	2.00
	Table conveyors, individual drives	[1]	[1]	[1]
	Table conveyors, group drives	[1]	[1]	[1]
	Table conveyors, reversing	[1]	[1]	[1]
	Wire drawing machines	1.35	1.50	1.75
	Flattening machines	[1]	[1]	[1]

1) Contact SEW-EURODRIVE
2) Contact SEW-EURODRIVE; dimensioning according to FEM1001

Field of application	Driven machine	Service factor operating period /day		
		< 3 h	3-10 h	> 10 h
Mills and drums	Dryers and coolers	-	1.50	1.60
	Kilns	-	-	2.00
	Ball mills	-	-	2.00
	Coal mills	-	1.50	1.75
Pumps	Centrifugal pumps	1.15	1.35	1.45
	Reciprocating (single-cylinder)	1.35	1.50	1.80
	Reciprocating (multi-cylinder)	1.20	1.40	1.50
	Spiral pumps	-	1.25	1.50
	Rotary (gear type, vane)	-	-	1.25
Lumber industry	Lumber industry	[1]	[1]	[1]
Mining industry	Crushers	1.55	1.75	2.00
	Screens and shakers	1.55	1.75	2.00
	Slewing drives	-	1.55	1.80
	Dredgers	[1]	[1]	[1]
Pulp and paper industry	Debarking Drums and Barkers	1.55	1.80	-
	Rolls (pick-up, wire drive, wire suction)	-	1.80	2.00
	Dryer cylinders (anti-friction bearings)	-	1.80	2.00
	Calenders (anti-friction bearings)	-	1.80	2.00
	Filters (pressure vacuum)	-	1.80	2.00
	Beaters and chippers	1.55	1.75	2.00
	Jordan mills	-	1.50	1.75
	Presses (bark, felt, size, suction)	-	-	1.75
	Reels	-	-	1.75
	Pulpers	[1]	[1]	[1]
	Washer filters	-	-	1.50
	Yankee cylinders (dryers)	[1]	[1]	[1]
Rubber and plastic industry	Extruders (plastic)	-	1.40	1.60
	Extruders (rubber)	-	1.50	1.80
	Rubber mills (2 in a row)	1.55	1.75	2.00
	Rubber mills (3 in a row)	-	1.50	1.75
	Warming mills	1.35	1.50	1.75
	Calenders	-	1.65	1.65
	Grinders	1.55	1.75	2.00
	Mixing mills	[1]	[1]	[1]
	Sheeters	1.55	1.75	2.00
	Refiners	1.55	1.75	2.00
	Tubers	[1]	[1]	[1]
Waste water treatment	Impeller areator	-	1.80	2.00
	Thickeners	1.15	1.25	1.50
	Vacuum filters	1.15	1.30	1.50
	Collectors	1.15	1.25	1.50
	Screw pump	-	1.30	1.50
	Brush areators	-	-	2.00

1) Contact SEW-EURODRIVE

Peak factor F_F

The peak factor F_F takes into account how often peak loads occur.

The permitted peak load depends on the frequency per hour and is calculated according to the following formula:

1. Based on torque

$$M_{K2\ zul} = \frac{2 \times M_{N2}}{F_F}$$

$M_{K2\ zul}$ = permitted peak torque at the gear unit output
M_{N2} = gear unit nominal torque
F_F = peak factor according to the following table

2. Based on power

$$P_{K1\ zul} = \frac{2 \times P_{N1}}{F_F}$$

$P_{K1\ zul}$ = permitted peak power at the gear unit input
P_{N1} = gear unit nominal power
F_F = peak factor according to the following table

	Frequency of peak load per hour					
	1...5	**6...20**	**21...40**	**41...80**	**81...160**	**> 160**
Peak factor F_F	1.00	1.20	1.30	1.50	1.75	2.00

STOP

The gear units may only be overloaded for a short period of time. Individual peak loads must not last for more than ten seconds.

5.3 Thermal rating P_T

The thermal rating P_T of a gear unit is the power that a gear unit can transmit continuously without exceeding a certain oil temperature. The thermal rating depends on the following factors:

- Type of lubricant used
- Ambient temperature
- Gear unit ratio
- Optional forced cooling methods (e.g. fan on HSS)
- Installation altitude of the gear unit (→ table, altitude factor f_1)
- Lubrication method of the gear unit (→ table, lubrication factor f_L)

For the following ambient conditions, the thermal rating can be directly read from the selection tables for

- ambient temperatures of 20°C or 40°C,
- natural cooling, or for cooling with fan (or two fans for MC2P units)
- altitudes < 1000 m ($f_1 = 1$)
- respective mounting positions
- splash (horizontal mounting position) or bath lubrication (vertical and upright mounting positions)

$$P_T = P_{TH} \times f_1 \times f_2 \times f_L \times f_T$$

P_{TH} = Nominal thermal rating of the gear unit. The values given in the selection tables in chapters 10 + 11 depend on the ambient temperature and cooling method.
For
20°C: $P_{TH\,[20]}$
40°C: $P_{TH\,[40]}$
with cooling fan
20°C: $P_{TH\,[20]}$
40°C: $P_{TH\,[40]}$
with two cooling fans
20°C: $P_{TH\,[20]}$
40°C: $P_{TH\,[40]}$

f_1 = Altitude factor

f_2 = Mounting option factor
1.07 = shaft mounted with torque arm
1.00 = all other mounting options

f_L = Lubrication factor
1.0 = splash and bath lubrication
1.1 = pressure lubrication

f_T = Ambient temperature factor
The selection tables already take account of different ambient temperatures; the factor is therefore only relevant for ambient temperatures above 40°C. For ambient temperatures of 30°C, the thermal rating can be interpolated

$$P_{TH\,[30]} = \frac{P_{TH\,[20]} + P_{TH\,[40]}}{2}$$

Altitude factor f_1

	Altitude H [m above sea level]				
	0	**1000**	**2000**	**3000**	**4000**
f_1[1)]	1.00	0.95	0.91	0.87	0.83

1) Intermediate values must be interpolated

Consult SEW-EURODRIVE in case of deviating conditions.

Ambient temperature factor f_T

Ambient temperature	**20°C**	**30°C**	**40°C**	**50°C**
f_T	1.0[1)]	1.0[1), 2)]	1.0[1)]	Contact SEW-EURODRIVE

1) The selection tables in chapter 5 already take account of different ambient conditions.

2) Interpolation between PTH[20] and PTH[40] in chapters 10 + 11 is possible

5.4 External radial and axial shaft loads

The permitted loads on the gear unit shaft depend on

- gear unit service factor
- required bearing lifetime
- direction of axial load (from or towards gear unit)
- application angle of radial load (rotating or at a specific position)
- position of radial load in relation to gear unit shaft shoulder
- relation of axial to radial load and vice versa

The limiting elements in a gear unit in terms of loads on the LSS depend on

- permitted load for the gear unit housing
- permitted force/stress of connection bolts of the gear unit foot or in the mounting flange
- permitted stress in the gear unit shaft
- minimum bearing life

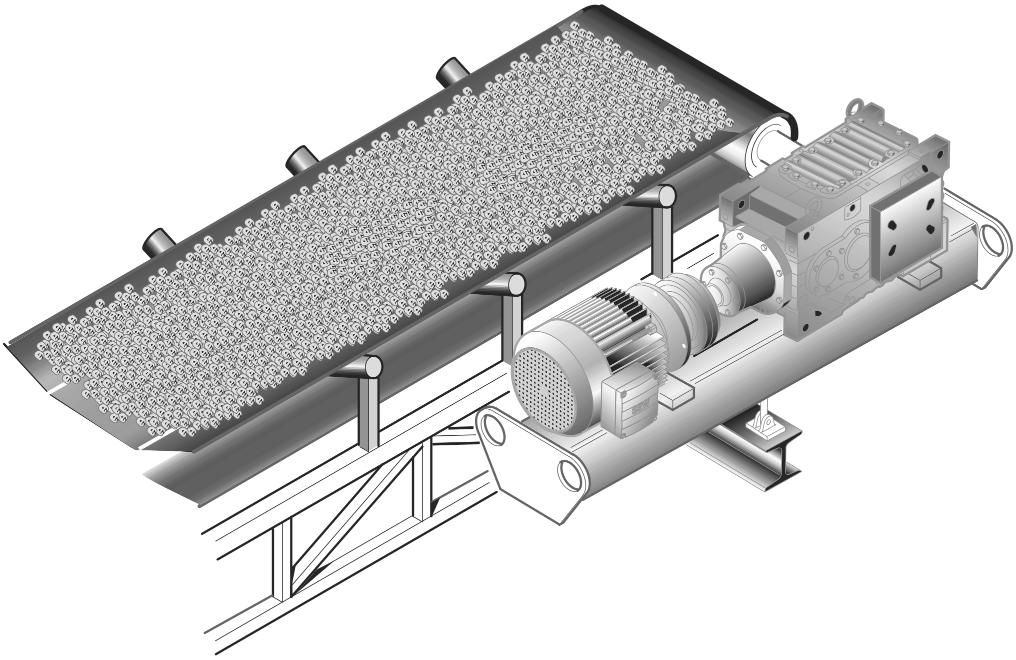
Based on these factors, the selection tables in chapters 10 + 11 show a radial load value that applies to the following conditions:

- Radial load is applied on the middle of the shaft
  - HSS: F_{RE}
  - LSS: F_{RA}
- The application angle of the radial load is applied at the most unfavourable position
- The applied axial load is 0!
- The gear unit service factor is F_S = 1.5 or higher
- The bearing life is equal or higher than a minimum value according to SEW standard

Contact SEW-EURODRIVE for deviating conditions. In many cases, higher loads can be applied.

5.5 Project planning example: Conveyor drive

Bulk material is to be transported from one point to another using a conveyor.



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Technical data and application conditions of bucket elevator gear units

- Foot-mounted gear unit with hollow shaft
- Output speed n_2 = 35 1/min
- Output torque M_{K2} = 9000 Nm
- Maximum output torque $M_{K2\ max}$ = 16 kNm
- Maximum input power $P_{K1\ max}$ = 61.4 kW
- Operating time: 16 hours per day
- The gear unit is started up once per hour (frequency of maximum output torque)
- The gear unit is to be used in a large hall under very dusty conditions and an ambient temperature range of ϑ_{amb} = 0°C ... 40°C
- Installation altitude H = 1000 m
- Min. service factor F_S = 1.4

Technical data of AC motors

- Input speed n_1 = 1500 1/min
- Motor power P_m = 45 kW

Step 1: Calculating the gear ratio

Calculate the gear unit reduction ratio i using the following formula:

$$i = \frac{n_1}{n_2} = \frac{1500\ 1/\text{min}}{35\ 1/\text{min}} = 42.86$$

i = ratio
n_1 = input speed
n_2 = required output speed

This value is used to specify the nominal gear ratio i_N = 45 (→ chapters 10 + 11).

Step 2: Calculating the operating power

The input power P_{K1} of the drive is calculated as follows using the output torque M_{K2} or output power P_{K2} as well as output speed n_2 and efficiency η:

$$P_{K1} = \frac{M_{K2} \times n_2}{9.550 \times} = \frac{9\ \text{kNm} \times 35\ 1/\text{min}}{9.550 \times 0.955} = 34.54\ \text{kW}$$

P_{K1} = input power
M_{K2} = output torque
η = efficiency (→ chapter 5.1)

(where η = 0.955 for three-stage gear units)

Step 3: Specifying gear unit size and gear unit reduction ratio

The required nominal power of the gear unit P_{N1} is calculated using input power P_{K1} and service factor F_S = 1.4 using the following formula:

$$P_{N1} \geq P_{K1} \times F_S$$

P_{N1} = 34.54 kW × 1.4 = 48.35 kW

This value is used to select the gear unit size MC3RLHF04 from the selection tables (→ chapter 11).

The selection of the gear unit provides the following technical data:

- Nominal power P_{N1} = 55.8 kW
- Nominal gear ratio i_N = 45 → exact gear ratio i_{ex} = 44.302
- Nominal gear unit torque M_{N2} = 15 kNm

Step 4: Calculating the permitted peak load

The permitted peak power $P_{K1\ zul}$ is calculated using nominal power P_{N1} and peak factor F_F (→ table, factor F_F):

$$P_{K1\ zul} = \frac{2 \times P_{N1}}{F_F} = \frac{2 \times 48.35\ \text{kW}}{0.87} = 111.6\ \text{kW}$$

$P_{K1\ zul}$ = permitted peak power on gear unit
P_{N1} = nominal power
F_F = peak factor

The permitted peak torque $M_{K2\ zul}$ is calculated using the nominal torque M_{N2} of the gear unit determined in step 3 and peak factor F_F (→ table, factor F_F).

$$M_{K2\ zul} = \frac{2 \times M_{N2}}{F_F} = \frac{2 \times 15\ \text{kNm}}{0.87} = 30\ \text{kNm}$$

$M_{K2\ zul}$ = permitted peak torque on gear unit output
M_{N2} = nominal gear unit torque
F_F = peak factor

Step 5: Checking the peak load

The maximum operating power $P_{K1\ max}$ must not exceed the permitted peak power P_{K1zul}!

$P_{K1\ max} \leq P_{K1\ zul}$
61.4 kW ≤ 111.6 kW

or

The maximum output torque $M_{K2\ max}$ must not exceed the permitted peak torque $M_{K2\ zul}$!

$M_{K2\ max} \leq M_{K2\ zul}$
16 kNm ≤ 30 kNm

This means you can use the selected gear unit size.

Step 6: Calculating the thermal rating

$P_T = P_{TH} \times f_1 \times f_2 \times f_L \times f_T$ = 29 kW × 1.0 × 1.0 × 1.0 = 29 kW

P_T = nominal thermal rating at 40°C of the gear unit
P_{TH} = thermal rating
f_1 = altitude factor
f_2 = mounting option factor
f_L = lubrication factor
f_T = ambient temperature factor

Higher thermal ratings are possible when using synthetic lubricants and special oil seals. Contact SEW-EURODRIVE in such cases.

Checking the thermal rating

The input power P_{K1} must not exceed the thermal rating P_T ($P_{K1} \leq P_T$).
Additional cooling is required if $P_{K1} > P_T$.

34.54 kW > 29 kW

→ Thermal rating not sufficient at 40°C

with one fan:

$P_T = P_{TH\,[40]} \times f_1 \times f_2 \times f_L \times f_T$ = 72 kW × 1.0 × 1.0 = 72 kW

P_T = nominal thermal rating at 40°C with one fan
P_{TH} = thermal rating
f_1 = altitude factor
f_2 = mounting option factor

5.6 Project planning example: Mixer drive

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Technical data and application conditions

A liquid with constant density is to be agitated.

- Helical gear unit with parallel shafts
- Vertical mounting position, solid output shaft
- Required output speed n_2 = 51 1/min
- Gear unit output power P_{K2} = 77 kW
- Peak input torque $M_{K1\ max}$ = 1.45 kNm
- Operating time: 24 hours per day
- The gear unit is started twice per day (frequency of maximum input torque)
- The gear unit is operated outdoors under a protective roof. Ambient temperature range: 0°C … 40°C, wind velocity approx. 3 m/s, normal humidity
- Installation altitude H = 500 m
- Connected to a mixer shaft with flexible coupling; mixer shaft is supported externally, no radial and axial loads on gear unit shaft
- Foot mounted gear unit

Technical data of AC motor

- Motor power P_M = 90 kW
- Nominal speed: n_M = 1485 1/min
- IEC size 280 M, flange ∅ 550 mm, shaft ∅ 75 mm x 140 mm

Step 1: Calculating the gear ratio

Calculate the gear unit reduction ratio i using the following formula:

$$i = \frac{n_1}{n_2} = \frac{1485\ 1/\text{min}}{51\ 1/\text{min}} = 29.12$$

i = ratio
n_1 = input speed
n_2 = required output speed

The value is used to specify the nominal gear ratio i_N = 28 (→ chapter 10)

Step 2: Calculating the operating power

The input power P_{K1} of the drive is calculated as follows using the output power P_{K2} or output torque M_{K2} as well as output speed n_2 and efficiency:

$$P_{K1} = \frac{P_{K2}}{\eta} = \frac{77\ \text{kW}}{0.955} = 80.6\ \text{kW}$$

P_{K1} = operating power
P_{K2} = gear unit output power
η = efficiency (→ chapter 5.1)

Step 3: Specifying the service factor F_S

If the customer does not specify the service factor, it can be determined according to the table in chapter 5.2.

Field of application:	Agitators and mixers
Driven machine:	Agitators for liquids
Operating period per day:	> 10 h

→ F_S = 1.5

Step 4: Specifying gear unit size and exact gear ratio

The required nominal power of the gear unit P_{N1} is calculated using operating power P_{K1} and service factor F_S using the following formula:

$P_{N1} \geq P_{K1} \times F_S$

$P_{N1} \geq 80.6\ \text{kW} \times 1.5 = 120.9\ \text{kW}$

Approximate required nominal gear unit torque M_{N2}:

$$M_{N2} = \frac{P_{N1}}{n_2} = \frac{120.9\ \text{kW}}{51\ \text{1/min}} \times 9.55 = 22.6\ \text{kNm}$$

M_{N2} = approximate required nominal gear unit torque
P_{N1} = required nominal power of the gear unit
n_2 = required output speed

Preselection on foldout page:

Torque class 25 kNm - Size 06 - Vertical - 1500 1/min

→ Chapters 10 + 11

- Nominal power: 134 kW
- Nominal ratio i_N = 28 → Exact ratio i_{ex} = 29.61
  → Output speed n_2 = 1485 1/min / 29.61 = 50.1 1/min
- Nominal gear unit torque: M_{N2} = 24.1 kNm
- Thermal rating at 40°C
  - 50 kW without fan
  - 115 kW with fan

Step 5: Calculating the permitted peak torque

The permitted peak torque $M_{K2\ zul}$ is calculated using the nominal torque M_{N2} of the gear unit determined in step 4 and factor F_F (→ table, factor F_F)

$$M_{K2\ zul} = \frac{2 \times M_{N2}}{F_F} = \frac{2 \times 24.1\ \text{kNm}}{1} = 48.2\ \text{kNm}$$

$M_{K2\ zul}$ = permitted peak torque
M_{N2} = nominal gear unit torque
n_2 = required output speed

Step 6: Checking maximum output torque

The max. output torque $M_{K2\ max}$ must not exceed the permitted output torque $M_{k2\ zul}$!

$M_{k2\ max} \leq M_{k2\ zul}$

with

$M_{K2\ max} = M_{k1\ max} \times i_{ex} \times \eta$ = 1.45 kNm × 29.61 × 0.955 = 41 kNm

$M_{K2\ max}$	= maximum output torque
$M_{K1\ max}$	= maximum input torque
i_{ex}	= required output speed
η	= efficiency (→ chapter 5.1)

→ 41.0 kNm ≤ 48.2 kNm

This means you can use the selected gear unit size

Step 7: Calculating the thermal rating

$P_T = P_{TH} \times f_1 \times f_2 \times f_L \times f_T$

P_T	= thermal rating
P_{TH}	= nominal thermal rating
f_1	= altitude factor
f_2	= mounting option factor
f_L	= lubrication factor
f_T	= ambient temperature factor

With P_{TH} from chapters 10 and 11:

f_1, f_2, f_L, f_T = 1.0

Without fan at 40°C:	P_T = 50 kW
With fan at 40°C:	P_T = 115 kW

Result:

Thermal rating without fan: 50 kW at an ambient temperature of 40°C

Thermal rating with fan: 115 kW at an ambient temperature of 40°C

Step 8: Checking the thermal rating

The operating power P_{K1} must not exceed the thermal rating of the gear unit.

$P_{K1} \leq P_T$

Without fan: 80.6 kW > 50 kW → thermal rating not sufficient!

Result:

With fan: 80.6 kW < 115 kW → thermal rating sufficient, fan required!

Step 9: Selecting the gear unit accessories

- Oil expansion tank made from cast iron for bath lubrication
- Double radial seals on LSS (standard for vertical units)
- Motor adapter for IEC motor 280
- Elastic coupling type ROTEX 65 on input shaft; one hub mounted on gear unit, other hub bored and keywayed for connecting the respective motor
- Fan in motor adapter