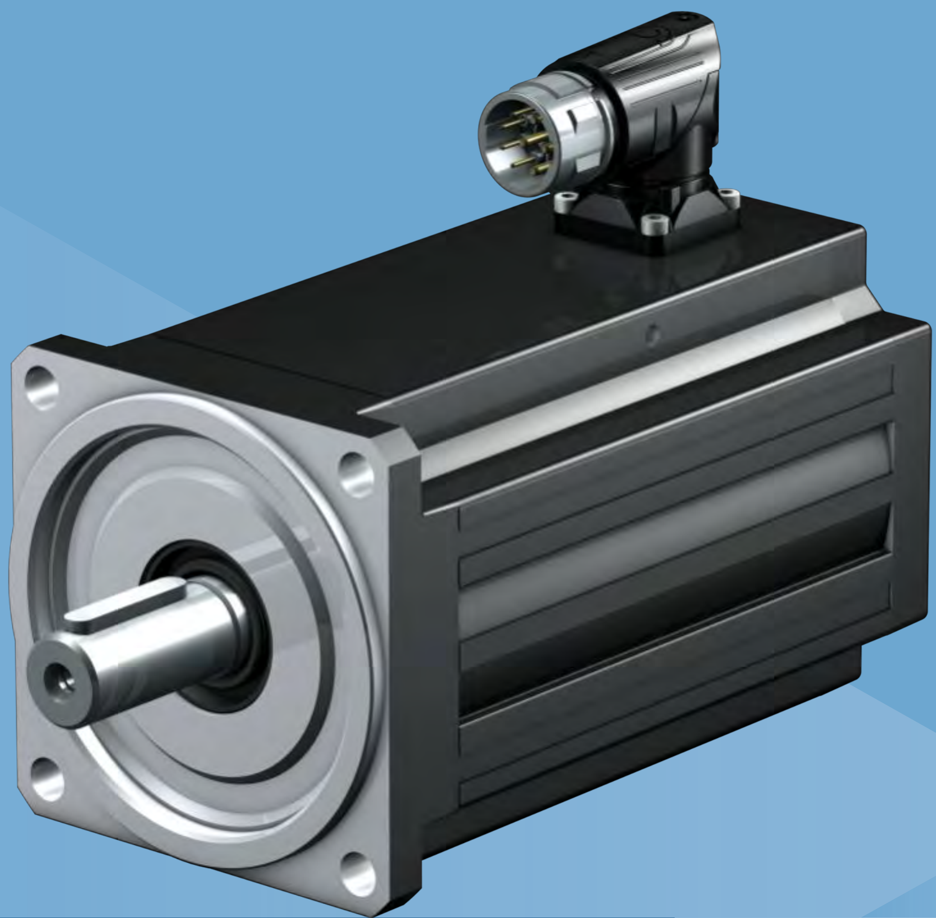


2 LM Lean motors

2.1 Overview

High-efficiency synchronous motors

Features

Higher energy efficiency than comparable IE4 asynchronous motors	✓
Energy efficiency IE5 in accordance with IEC/TS 60034-30-2	✓
Higher acceleration performance than asynchronous motors	✓
Substantially lighter and more compact than comparable asynchronous motors	✓
Rugged thanks to absence of the encoder	✓
Wiring reduced to the power connection cable	✓
Rotating plug connector with quick lock	✓

Technical data

M_N	2.36 – 25.7 Nm
M_0	2.29 – 29.8 Nm

2.2 Selection tables

The technical data specified in the selection tables applies to:

- Installation altitudes up to 1000 m above sea level
- Surrounding temperatures from −15 °C to +40 °C
- Operation on a STOBER drive controller
- DC link voltage U_{ZK} = DC 540 V
- Coating: RAL 9005 Jet black, matte

In addition, the technical data applies to an uninsulated design with the following thermal mounting conditions:

Type	Dimensions of steel mounting flange (thickness x width x height)	Convection surface area Steel mounting flange
LM4, LM5	23 x 210 x 275 mm	0.16 m^2
LM7	28 x 300 x 400 mm	0.3 m^2

Note the differing ambient conditions in Chapter [2.7.3]

An explanation of the formula symbols can be found in the Chapter [15.1].

Type	K_{EM} [V/1000 rpm]	n_N [rpm]	M_N [Nm]	I_N [A]	$K_{M,N}$ [Nm/A]	P_N [kW]	η_{mot} [%]	M_0 [Nm]	I_0 [A]	M_R [Nm]	M_{max} <1000 rpm [Nm]	I_{max} <1000 rpm [A]	M_{max} ≥1000 rpm [Nm]	I_{max} ≥1000 rpm [A]	J [10^{-4} kgm²]	m [kg]
LM401U	100	3000	2.36	1.82	1.30	0.74	82.93	2.29	1.82	0.04	3.77	2.76	4.51	3.31	1.67	4.42
LM402U	120	3000	4.41	2.88	1.53	1.4	87.63	4.50	2.94	0.04	7.84	4.96	9.70	6.16	3.01	6.08
LM403U	120	3000	6.06	3.92	1.55	1.9	90.26	6.19	4.08	0.04	11.5	7.02	12.8	7.85	4.31	7.62
LM503U	135	3000	9.48	5.62	1.69	3.0	92.95	10.1	5.95	0.06	18.3	10.6	20.4	11.8	10.4	10.5
LM505U	135	3000	13.7	7.83	1.75	4.3	94.48	15.5	8.83	0.06	27.2	15.0	32.1	17.8	16.8	15.1
LM704U	145	3000	19.3	10.6	1.81	6.1	95.05	21.3	11.6	0.23	38.8	20.0	41.2	22.3	36.5	20.9
LM706U	140	3000	25.7	14.7	1.75	8.1	95.59	29.8	16.8	0.23	51.5	27.7	61.4	31.7	53.8	28.0

The efficiency η_{mot} was determined based on the standards IEC/TS 60034-30-2 and DIN IEC 60034-2-3.

2.3 Torque/speed curves

Torque/speed curves depend on the nominal speed and/or winding design of the motor and the DC link voltage of the drive controller that is used. The following torque/speed curves apply to the DC link voltage DC 540 V.

At 1000 rpm, the measurement process for detecting the rotor position switches depending on the system, so that the maximum torque of the Lean motor is available as of 1000 rpm.

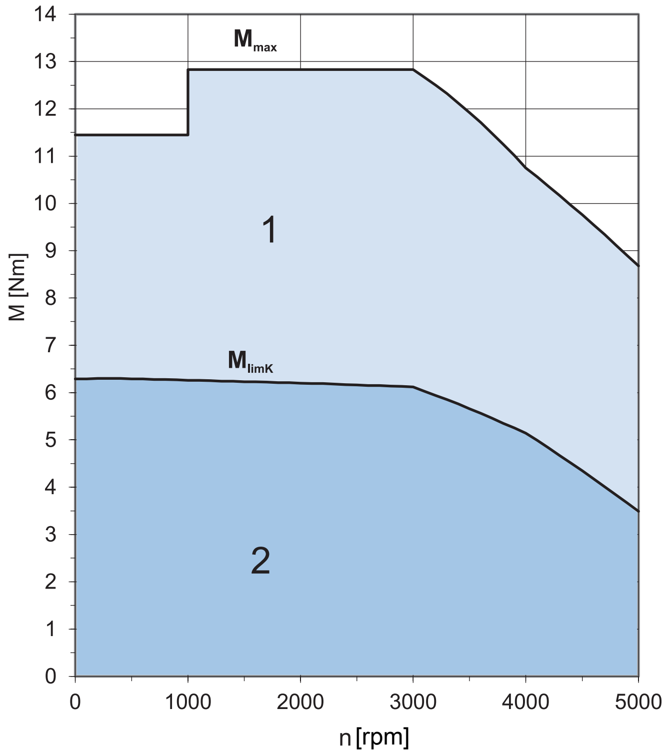
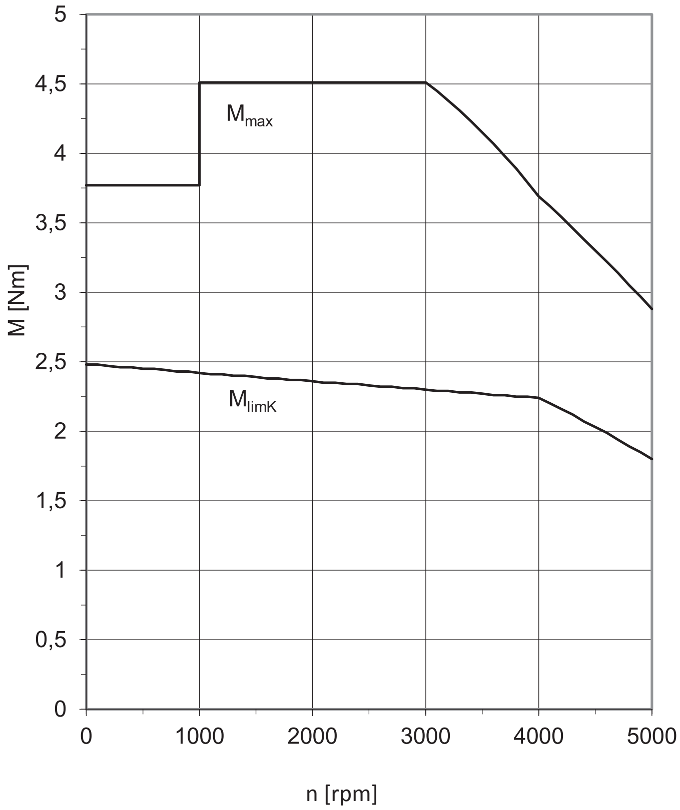


Fig. 1: Explanation of a torque/speed curve

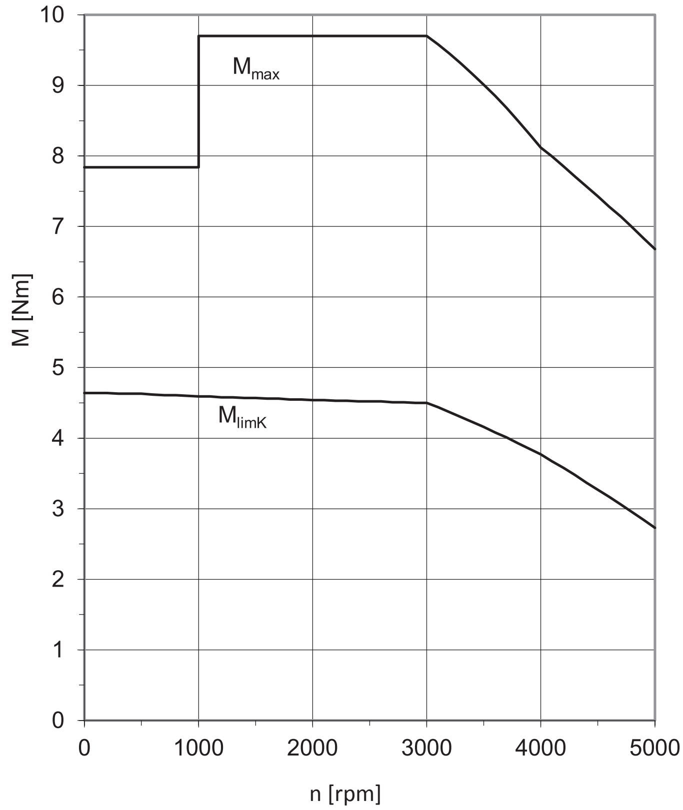
1 Torque range for brief operation (ED_{10} < 100%) with Δϑ = 100 K

2 Torque range for continuous operation with constant load (S1 mode, ED_{10} = 100%) with Δϑ = 100 K

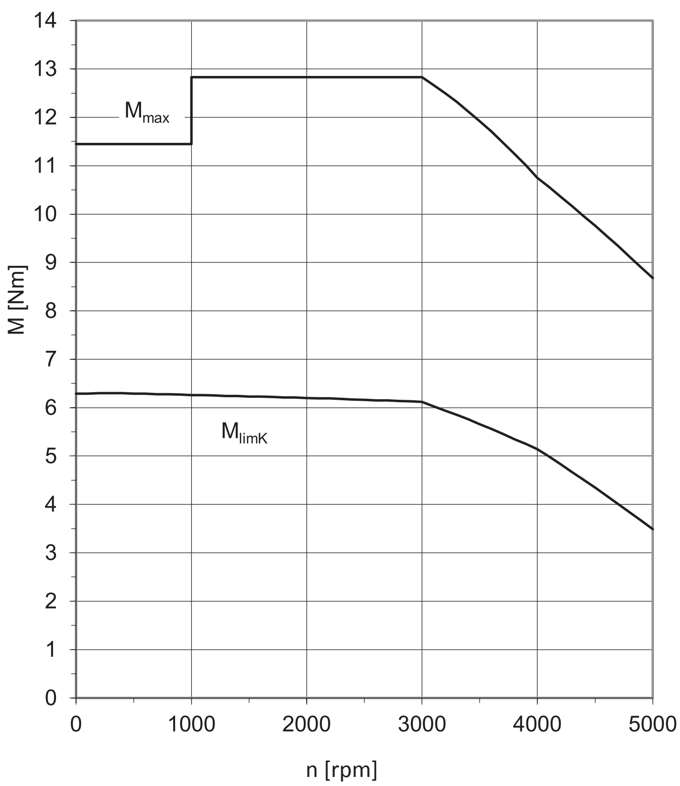
LM401U (n_N=3000 rpm)

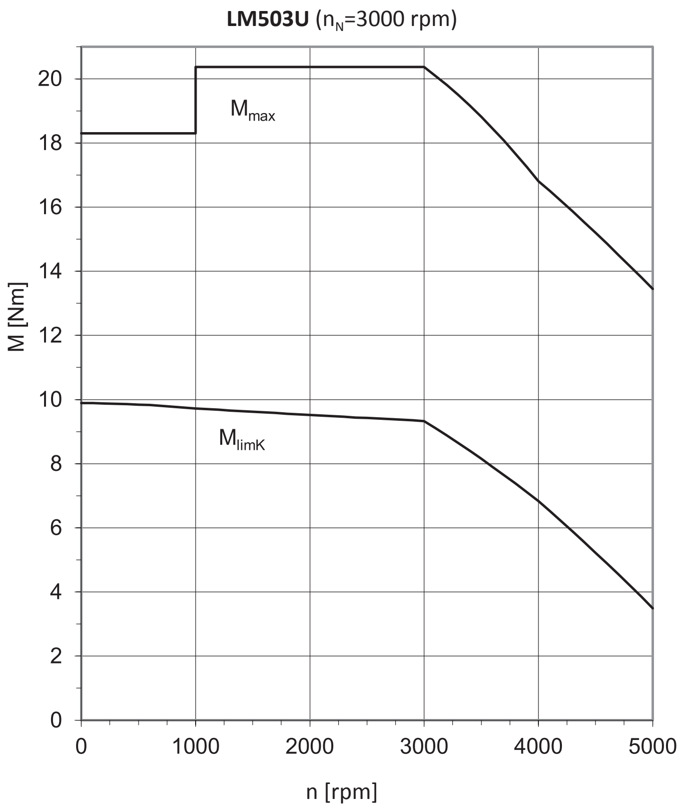


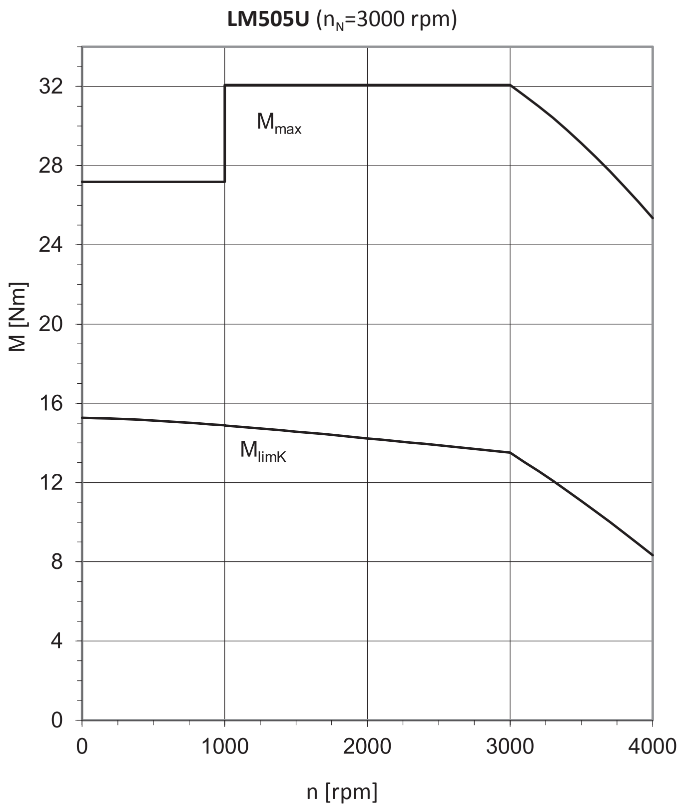
LM402U (n_N=3000 rpm)

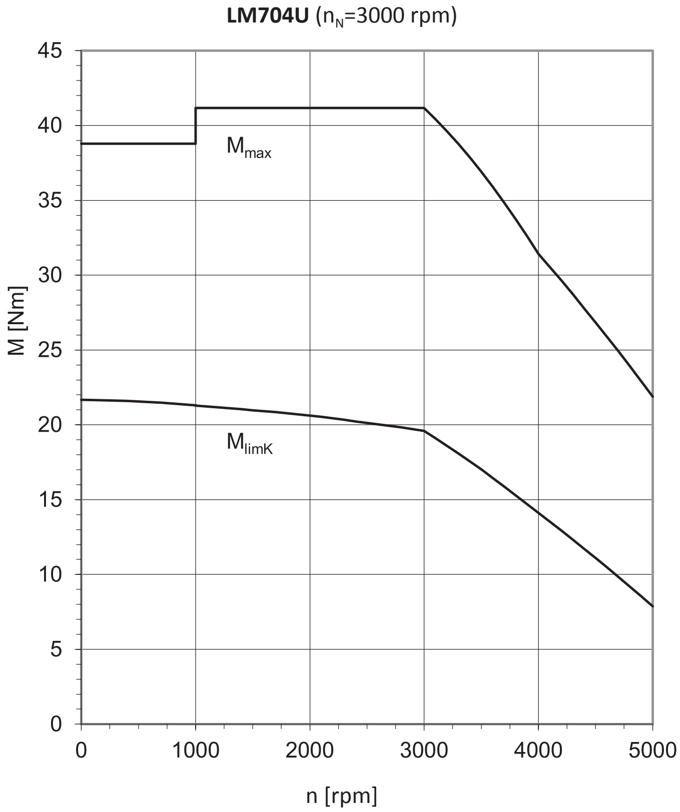


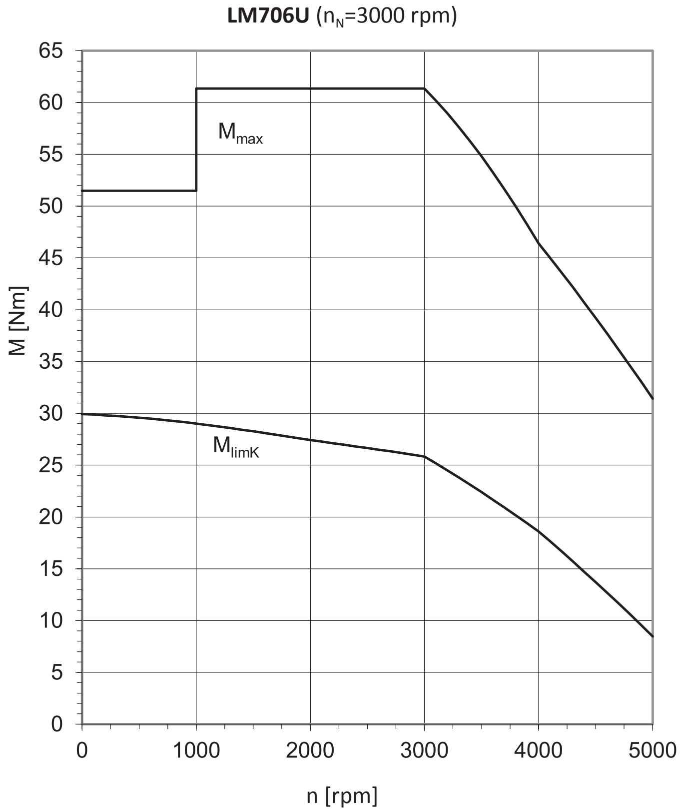
LM403U (n_N=3000 rpm)




LM503U (n_N=3000 rpm)
M [Nm]
n [rpm]
M_{max}
M_{limK}
0
2
4
6
8
10
12
14
16
18
20
0
1000
2000
3000
4000
5000


LM505U (n_N=3000 rpm)
M [Nm]
n [rpm]
M_{max}
M_{limK}
0
4
8
12
16
20
24
28
32
0
1000
2000
3000
4000


LM704U (n_N=3000 rpm)
M [Nm]
n [rpm]
M_{max}
M_{limK}
0
5
10
15
20
25
30
35
40
45
0
1000
2000
3000
4000
5000


LM706U (n_N=3000 rpm)
M [Nm]
n [rpm]
M_{max}
M_{limK}
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0
1000
2000
3000
4000
5000

2.4 Dimensional drawings

In this chapter, you can find the dimensions of the motors.

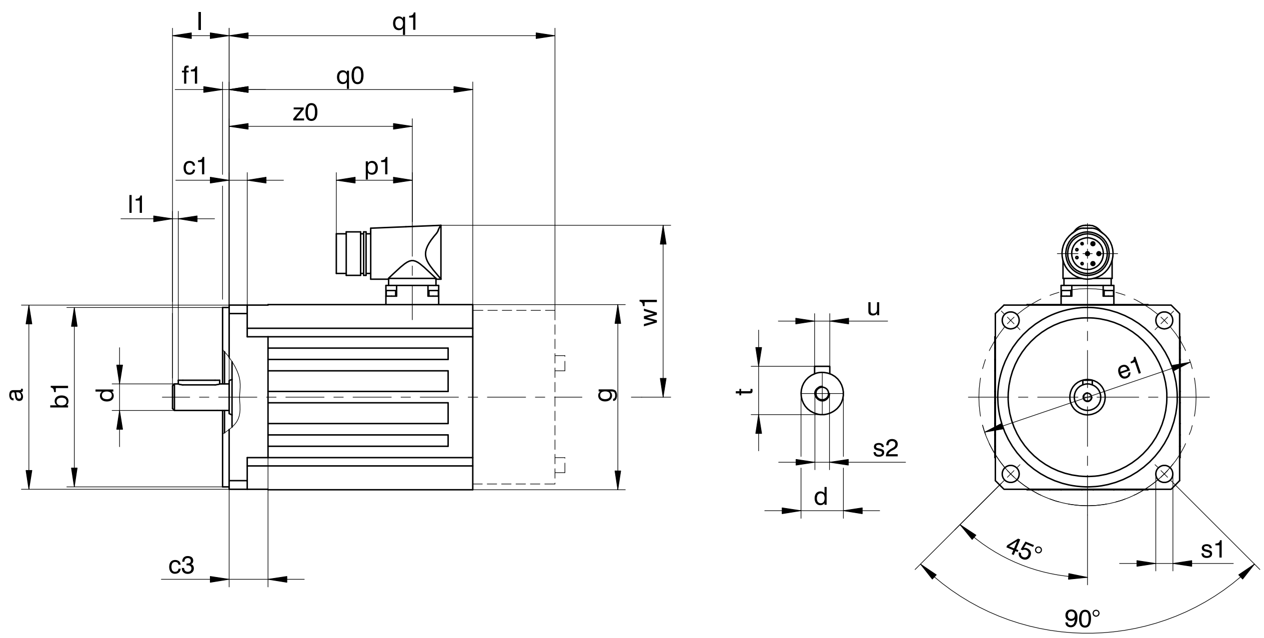
Dimensions can exceed the specifications of ISO 2768-mK due to casting tolerances or accumulation of individual tolerances.

We reserve the right to make dimensional changes due to ongoing technical development.

You can download CAD models of our standard drives at http://cad.stoeber.de.

Centering holes in solid shafts in accordance with DIN 332-2, DR shape

Thread size	M4	M5	M6	M8	M10	M12	M16	M20	M24
Thread depth [mm]	10	12.5	16	19	22	28	36	42	50



q0 Applies to motors without brake.

q1 Applies to motors with brake.

Type	□a	∅b1	c1	c3	∅d	∅e1	f1	□g	l	l1	p1	q0	q1	∅s1	s2	t	u	w1	z0
LM401U	98	95_{j6}	9.5	20.5	14_{k6}	115	3.5	98	30	3	40	129.0	172.5	9	M5	16.0	A5×5×22	91	97
LM402U	98	95_{j6}	9.5	20.5	19_{k6}	115	3.5	98	40	3	40	168.0	211.5	9	M6	21.5	A6×6×32	91	136
LM403U	98	95_{j6}	9.5	20.5	19_{k6}	115	3.5	98	40	3	40	199.0	242.5	9	M6	21.5	A6×6×32	91	167
LM503U	115	110_{j6}	10.0	16.0	24_{k6}	130	3.5	115	50	3	40	202.5	250.5	9	M8	27.0	A8×7×40	100	172
LM505U	115	110_{j6}	10.0	16.0	24_{k6}	130	3.5	115	50	3	40	272.5	320.5	9	M8	27.0	A8×7×40	100	242
LM704U	145	130_{j6}	10.0	19.0	24_{k6}	165	3.5	145	50	3	40	255.5	314.5	11	M8	27.0	A8×7×40	115	223
LM706U	145	130_{j6}	10.0	19.0	32_{k6}	165	3.5	145	58	3	40	325.5	384.5	11	M12	35.0	A10×8×50	115	293

2.5 Type designation

Sample code

LM	4	0	1	U	S	AR	O	100

Explanation

Code	Designation	Design
LM	Type	Lean motor
4	Size	4 (example)
0	Generation	0
1	Length	1 (example)
U	Cooling	Convection cooling
S	Design	Standard
AR	Drive controller	SC6
AT		SI6
O	Brake	Without holding brake
F		Spring-loaded holding brake
100	Electromagnetic constant (EMC) K_{EM}	100 V/1000 rpm (example)

2.6 Product description

2.6.1 General features

Feature	Description
Design	Sensorless synchronous motor with interior permanent magnets
Design	IM B5, IM V1, IM V3 in accordance with EN 60034-7
Protection class	IP56 / IP66 (option)
Thermal class	155 (F) in accordance with EN 60034-1 (155 °C, heating $\Delta\vartheta$ = 100 K)
Surface	Matte black as per RAL 9005
Cooling	IC 410 convection cooling
Bearing	Rolling bearing with lifetime lubrication and non-contact sealing
Sealing	Radial shaft seal rings made of FKM (A side)
Shaft	Shaft with feather key, diameter quality k6
Radial runout	Normal tolerance class in accordance with IEC 60072-1
Concentricity	Normal tolerance class in accordance with IEC 60072-1
Axial runout	Normal tolerance class in accordance with IEC 60072-1
Vibration intensity	A in accordance with EN 60034-14
Noise level	Limit values in accordance with EN 60034-9

Note

Repainting the motor changes its thermal properties. This lowers the performance limit of the motor.

2.6.2 Electrical features

General electrical features of the motor are described in this chapter. Details can be found in the "Selection tables" chapter.

Feature	Description
DC link voltage	DC 540 V (max. 620 V) on STOBER drive controllers
Winding	Three-phase
Circuit	Star, center not led through
Protection class	I (protective grounding) in accordance with EN 61140
Number of pole pairs	3

2.6.3 Ambient conditions

Standard ambient conditions for transport, storage and operation of the motor are described in this chapter. Information about differing ambient conditions can be found in the chapter [▹ 2.7.3].

Feature	Description
Surrounding temperature for transport/storage	−30 °C to +85 °C
Surrounding temperature for operation	−15 °C to +40 °C
Installation altitude	≤ 1000 m above sea level
Shock load	≤ 50 m/s^2 (5 g), 6 ms in accordance with EN 60068-2-27

Notes

- STOBER Lean motors are not suitable for potentially explosive atmospheres in accordance with (ATEX) Directive 2014/34/EU.
- Secure the power cable close to the motor so that vibrations of the cable do not place impermissible loads on the motor plug connector.
- Note that the braking torques of the holding brake (optional) may be reduced by shock loading.
- Also take into consideration the shock load of the motor due to output units (such as gear units and pumps) which are coupled with the motor.

To prevent damage, protect the motor from the following influences:

- Environments with harmful oils, acids, gases, vapors, dust or radiation
- Extreme temperature fluctuations with high humidity
- Thawing or icing
- Strong UV radiation (e.g. direct sunlight)
- Presence of salt spray
- Shaking, impacts, vibrations and high acceleration
- Sparks or heat

2.6.4 Positioning behavior

Lean motors do not have an encoder installed. Instead, they exhibit anisotropic behavior where the winding inductance depends on the rotor position. The drive controller sends electric signals through the motor windings and calculates the rotor position of the motor based on the received signals. As a result, Lean motors can be used as servo drives in applications for which a positioning accuracy of ± 1° and speed ripple factor ≤ 1% is sufficient. The speed and torque of the Lean motors can be set to any point from a standstill to maximum speed with full torque control.

2.6.5 Possible combinations with drive controllers

The Lean motor can be operated only with STOBER SC6 or SI6 drive controllers. For detailed information about the drive controllers, refer to the corresponding chapter in this catalog.

2.6.6 Temperature sensor

In this chapter, you can find technical data on the temperature sensor installed in STOBER Lean motors for implementing thermal winding protection. To prevent damage to the motor, always monitor the temperature sensor with appropriate devices that will turn off the motor if the maximum permitted winding temperature is exceeded.

You can find information about the electrical connection of the temperature sensor in the "Connection method" chapter.

2.6.6.1 PTC thermistor

The PTC thermistor is installed as a standard temperature sensor in STOBER Lean motors.

The PTC thermistor is a triple thermistor in accordance with DIN 44082 that can be used for monitoring the temperature of each winding phase. The resistance values in the following table and curve refer to a single thermistor in accordance with DIN 44081. These values must be multiplied by 3 for a triple thermistor in accordance with DIN 44082.

Feature	Description
Nominal response temperature ϑ_{NAT}	145 °C ± 5 K
Resistance R −20 °C up to ϑ_{NAT} − 20 K	≤ 250 Ω
Resistance R with ϑ_{NAT} − 5 K	≤ 550 Ω
Resistance R with ϑ_{NAT} + 5 K	≥ 1330 Ω
Resistance R with ϑ_{NAT} + 15 K	≥ 4000 Ω
Operating voltage	≤ DC 7.5 V
Thermal response time	< 5 s
Thermal class	155 (F) in accordance with EN 60034-1 (155 °C, heating $\Delta\vartheta$ = 100 K)

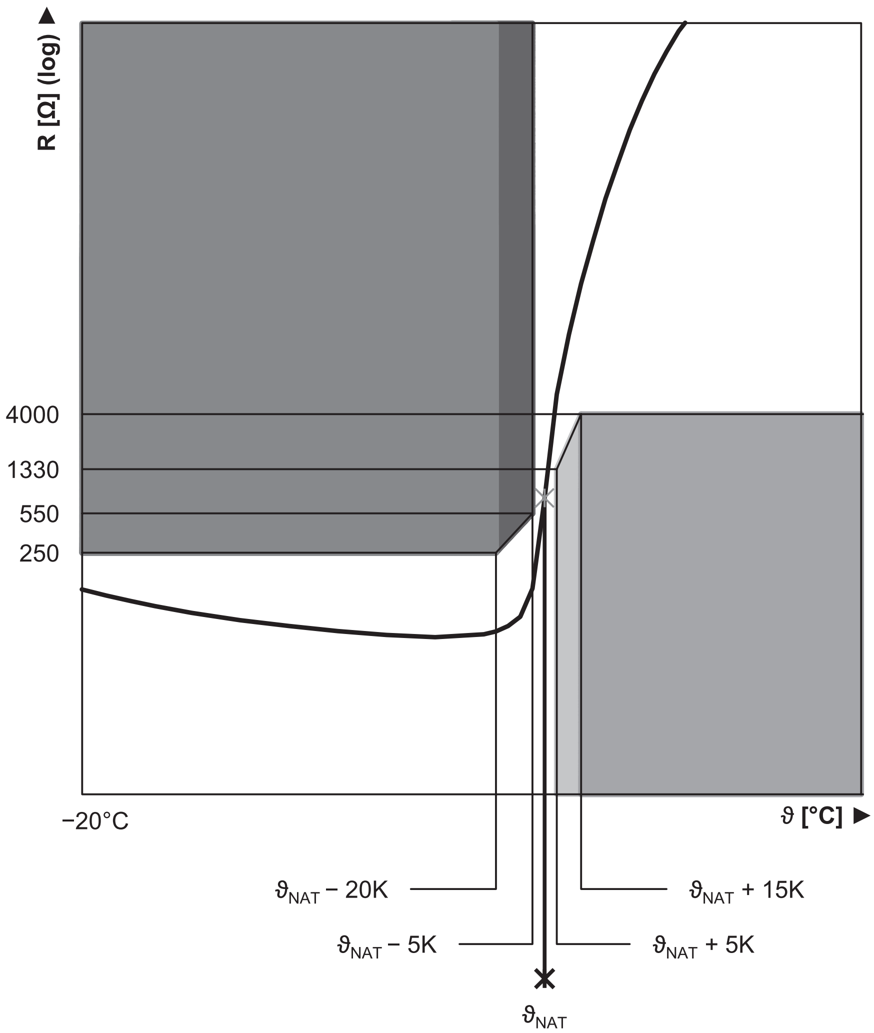


Fig. 2: PTC thermistor curve (single thermistor)

2.6.7 Cooling

A Lean motor is cooled by convection cooling (IC 410 in accordance with EN 60034-6). The air flowing around the motor is heated by the radiated motor heat and rises.

2.6.8 Holding brake

STOBER Lean motors can be optionally equipped with a spring-loaded holding brake in order to secure the motor shaft when the motor is at a standstill. The holding brake engages automatically if the voltage drops.

Nominal voltage of the spring-loaded holding brake: DC 24 V ± 10%, any polarity.

Observe the following during project configuration:

- The holding brake is designed to keep the motor shaft from moving. Activate braking processes during operation using the corresponding electrical functions of the drive controller. In exceptional circumstances, the holding brake can be used for braking from full speed (following a power failure or when setting up the machine). The maximum permitted work done by friction $W_{B,Rmax/h}$ may not be exceeded.
- Note that the braking torque M_{Bdyn} may initially be up to 50% less when braking from full speed. As a result, the braking effect has a delayed action and braking distances become longer.
- Regularly perform a brake test to ensure the functional safety of the brakes. Details can be found in the documentation of the motor and the drive controller.
- The holding brake of the motor does not offer adequate safety for persons in the hazardous area of gravity-loaded vertical axes. Therefore take additional measures to minimize risk, e.g. by providing a mechanical substructure for maintenance work.
- Take into consideration voltage losses in the connection cables that connect the voltage source to the holding brake connections.
- The holding torque of the brake can be reduced by shock loading. Information about shock loading can be found in the "Ambient conditions" chapter.

Calculation of work done by friction per braking process

$$W_{B,R/B} = \frac{J_{tot} \cdot n^2}{182.4} \cdot \frac{M_{Bdyn}}{M_{Bdyn} \pm M_L}$$

The sign of M_L is positive if the movement runs vertically upwards or horizontally and it is negative if the movement runs vertically down.

Calculation of the stop time

$$t_{dec} = 2.66 \cdot t_{1B} + \frac{n \cdot J_{tot}}{9.55 \cdot M_{Bdyn}}$$

Switching behavior

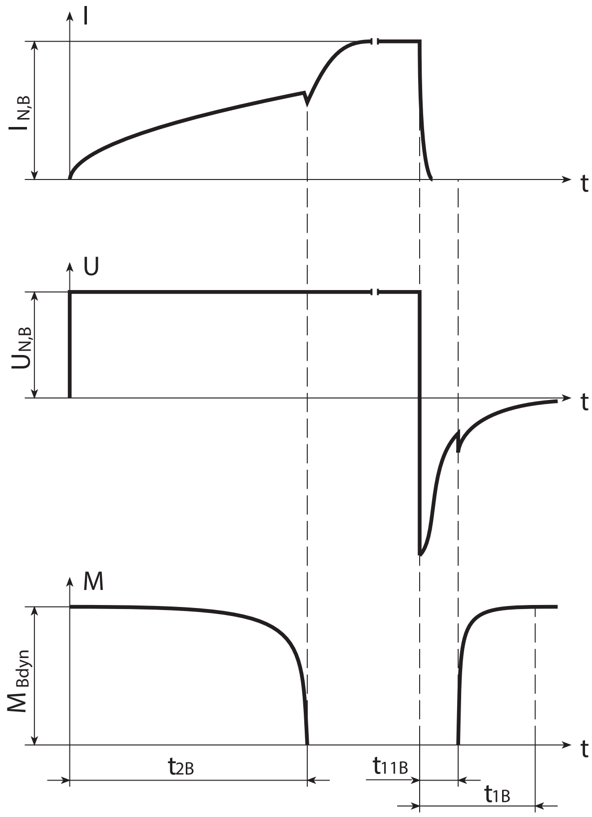


Fig. 3: Holding brake – Switching behavior

Technical data

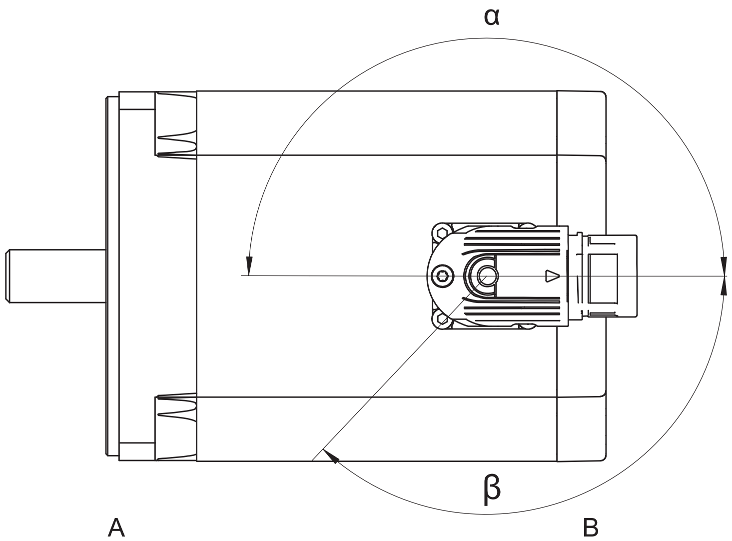
Type	M_{Bstat} [Nm]	M_{Bdyn} [Nm]	$I_{N,B}$ [A]	$W_{B,Rmax/h}$ [kJ]	$N_{B,stop}$	$J_{B,stop}$ [10^{-4}kgm²]	$W_{B,Rlim}$ [kJ]	t_{2B} [ms]	t_{11B} [ms]	t_{1B} [ms]	$x_{B,N}$ [mm]	ΔJ_B [10^{-4}kgm²]	Δm_B [kg]
LM401	8.0	7.0	0.90	3.0	428000	3.78	8000	50	12	33	0.2	0.219	1.80
LM402	8.0	7.0	0.90	3.0	250000	6.47	8000	50	12	33	0.2	0.219	1.80
LM403	8.0	7.0	0.90	3.0	178000	9.06	8000	50	12	33	0.2	0.219	1.80
LM503	16	13	0.90	6.0	119000	22.1	13000	60	16	14	0.3	0.686	2.80
LM505	16	13	0.90	6.0	75000	34.9	13000	60	16	14	0.3	0.686	2.80
LM704	32	20	1.9	7.0	53000	76.4	20000	90	25	50	0.2	1.771	4.80
LM706	32	20	1.9	7.0	36000	111	20000	90	25	50	0.2	1.771	4.80

2.6.9 Connection method

2.6.9.1 Plug connectors

Lean motors are equipped with a twistable quick-lock plug connector in the standard version. Details can be found in this chapter.

The figures represent the position of the plug connectors upon delivery.



A	Attachment or output side of the motor	B	Rear side of the motor

Plug connector features

Motor type	Size	Connection	Turning range	
			α	β
LM4 – LM7	con.23	Quick lock	180°	135°

The number in the designation of the plug connector size indicates approximately the external thread diameter of the plug connector in mm (for example con.23 designates a plug connector with an external thread diameter of about 23 mm).

2.6.9.2 Connection of the motor housing to the grounding conductor system

Connect the motor housing to the grounding conductor system of the machine in order to prevent personal injury and faulty triggering of residual current protective devices.

All attachment parts required for the connection of the grounding conductor to the motor housing are delivered with the motor. The grounding screw of the motor is identified with the symbol ⏚ in accordance with IEC 60417-DB. The cross-section of the grounding conductor has to be at least as large as the cross-section of the lines in the power connection.

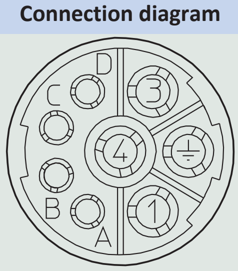
2.6.9.3 Terminal assignment

The terminal assignment of Lean motors in the standard version is described in this chapter. For more information, refer to the connection plan included in the delivery of every motor.

The colors of the connecting wires inside the motor are specified in accordance with IEC 60757.

Power connection

Plug connector size con.23 (1)

Connection diagram	Pin	Connection	Color
	1	1U1 (U phase)	black
	3	1V1 (V phase)	blue
	4	1W1 (W phase)	red
	A	1BD1 (brake +)	
	B	1BD2 (brake –)	
	C	1TP1/1K1 (temperature sensor)	
	D	1TP2/1K2 (temperature sensor)	
	⏚	PE (grounding conductor)	green-yellow

2.7 Project configuration

Project your drives using our SERVOsoft designing software. You can receive SERVOsoft for free from your adviser at one of our sales centers. Observe the limit conditions in this chapter to ensure a safe design for your drives.

An explanation of the formula symbols can be found in Chapter Symbols in formulas.

2.7.1 Calculation of the operating point

In this chapter, you can find information needed to calculate the operating point.

Check the following conditions for operating points other than the nominal point M_N specified in the selection tables:

$n_{m*} \leq n_N$

$M_{eff*} \leq M_{limK}$

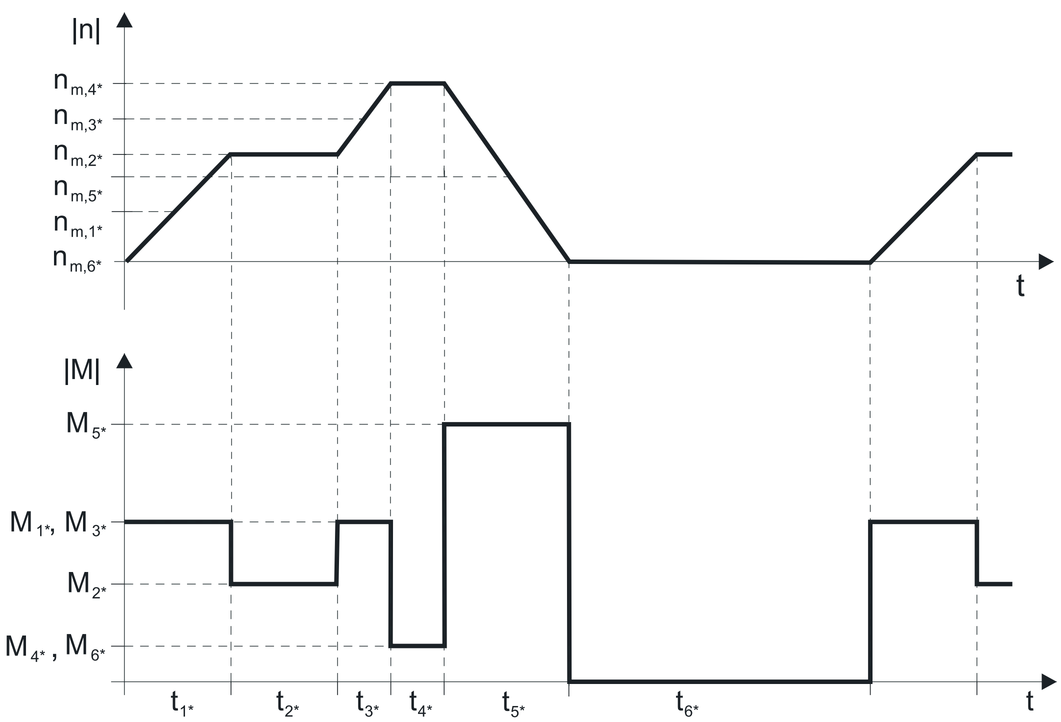
$M_{max*} < M_{max}$

The values for M_N, n_N, M_{max} can be found in the selection tables.

The values for M_{limK} can be found in the torque/speed characteristic curves.

Example of cyclic operation

The following calculations refer to a representation of the power delivered at the motor shaft based on the following example:



Calculation of the actual average input speed

$$n_{m*} = \frac{|n_{m,1*}| \cdot t_{1*} + \ldots + |n_{m,n*}| \cdot t_{n*}}{t_{1*} + \ldots + t_{n*}}$$

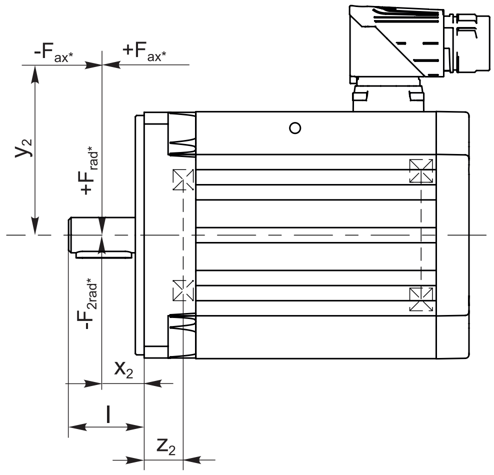
If $t_{1*} + \ldots + t_{5*} \geq 10$ min, determine n_{m*} without the rest phase t_{6*}.

Calculation of the actual effective torque

$$M_{eff*} = \sqrt{\frac{t_{1*} \cdot M_{1*}^2 + \ldots + t_{n*} \cdot M_{n*}^2}{t_{1*} + \ldots + t_{n*}}}$$

2.7.2 Permitted shaft loads

The shaft loads permitted for the Lean motor are defined in this chapter.



Permitted shaft loads

Type	z_2 [mm]	F_{ax100} [N]	F_{rad100} [N]	M_{k100} [Nm]
LM401	19.5	550	1800	62
LM402	19.5	550	1800	71
LM403	19.5	550	1800	71
LM503	19.5	750	2400	107
LM505	19.5	750	2400	107
LM704	24.5	1300	4200	208
LM706	24.5	1300	4200	225

The values specified in the tables apply to the permitted shaft loads:

- For shaft dimensions in accordance with the catalog
- A force applied at the center of the output shaft: $x_2 = l / 2$ (shaft dimensions can be found in the chapter Dimensional drawings)
- Output speeds $n_{m*} \leq 100$ rpm ($F_{ax} = F_{ax100}$; $F_{rad} = F_{rad100}$; $M_k = M_{k100}$)

The following applies to output speeds $n_{m*} > 100$ rpm:

$$F_{ax} = \frac{F_{ax100}}{\sqrt[3]{\frac{n_{m*}}{100\text{ rpm}}}} \qquad F_{rad} = \frac{F_{rad100}}{\sqrt[3]{\frac{n_{m*}}{100\text{ rpm}}}} \qquad M_k = \frac{M_{k100}}{\sqrt[3]{\frac{n_{m*}}{100\text{ rpm}}}}$$

The following applies to other force application points:

$$M_{k*} = \frac{2 \cdot F_{ax*} \cdot y_2 + F_{rad*} \cdot (x_2 + z_2)}{1000} \leq M_{k100}$$

$$F_{rad*} \leq F_{rad100}$$

$$F_{ax*} \leq F_{ax100}$$

For applications with multiple axial and/or radial forces, you must add the forces as vectors.

2.7.3 Derating

If you use the motor under ambient conditions that differ from the standard ambient conditions, the nominal torque M_N of the motor is reduced. In this chapter, you can find information for calculating the reduced nominal torque.

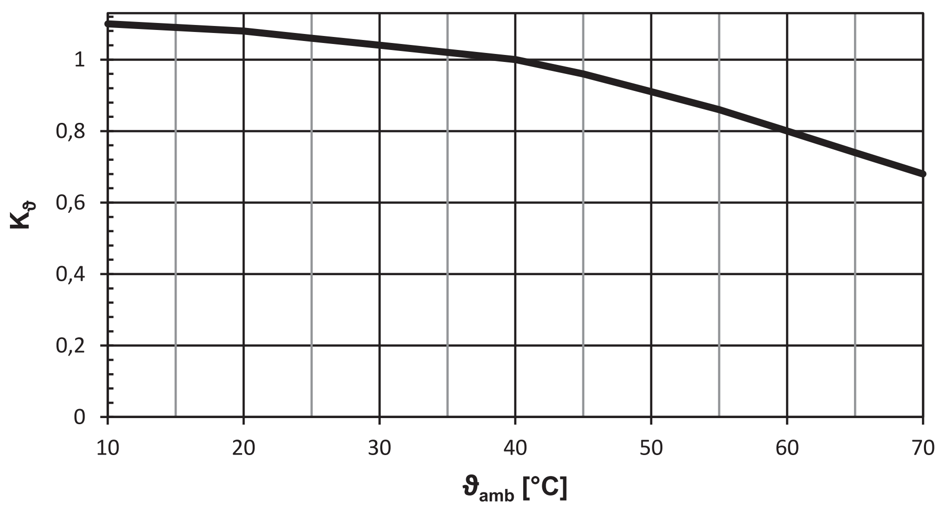


Fig. 4: Derating depending on the surrounding temperature

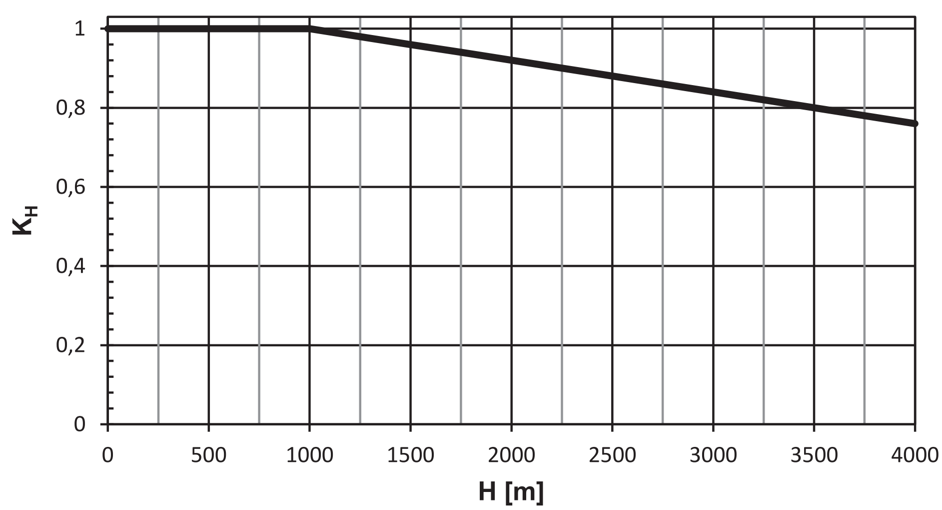


Fig. 5: Derating depending on the installation height

Calculation

If surrounding temperature ϑ_{amb} > 40 °C:

$M_{Nred} = M_N \cdot K_\vartheta$

If installation altitude H > 1000 m above sea level:

$M_{Nred} = M_N \cdot K_H$

If the surrounding temperature ϑ_{amb} > 40 °C and installation altitude H > 1000 m above sea level:

$M_{Nred} = M_N \cdot K_H \cdot K_\vartheta$

2.8 Further information

2.8.1 Directives and standards

STOBER Lean motors meet the requirements of the following directives and standards:

- (Low Voltage) Directive 2014/35/EU
- EN 60034-1:2010 + Cor.:2010
- EN 60034-5:2001 + A1:2007
- EN 60034-6:1993

2.8.2 Identifiers and test symbols

Lean motors have the following marks and test symbols:

CE mark: The product meets the requirements of EU directives.

cURus test symbol "Servo and Stepper Motors – Component"; registered under UL number E488992 with Underwriters Laboratories USA (optional).

2.8.3 Additional documentation

Additional documentation related to the product can be found at http://www.stoeber.de/en/download

Enter the ID of the documentation in the Search... field.

Documentation	ID
Operating manual for LM Lean motors	443048_en