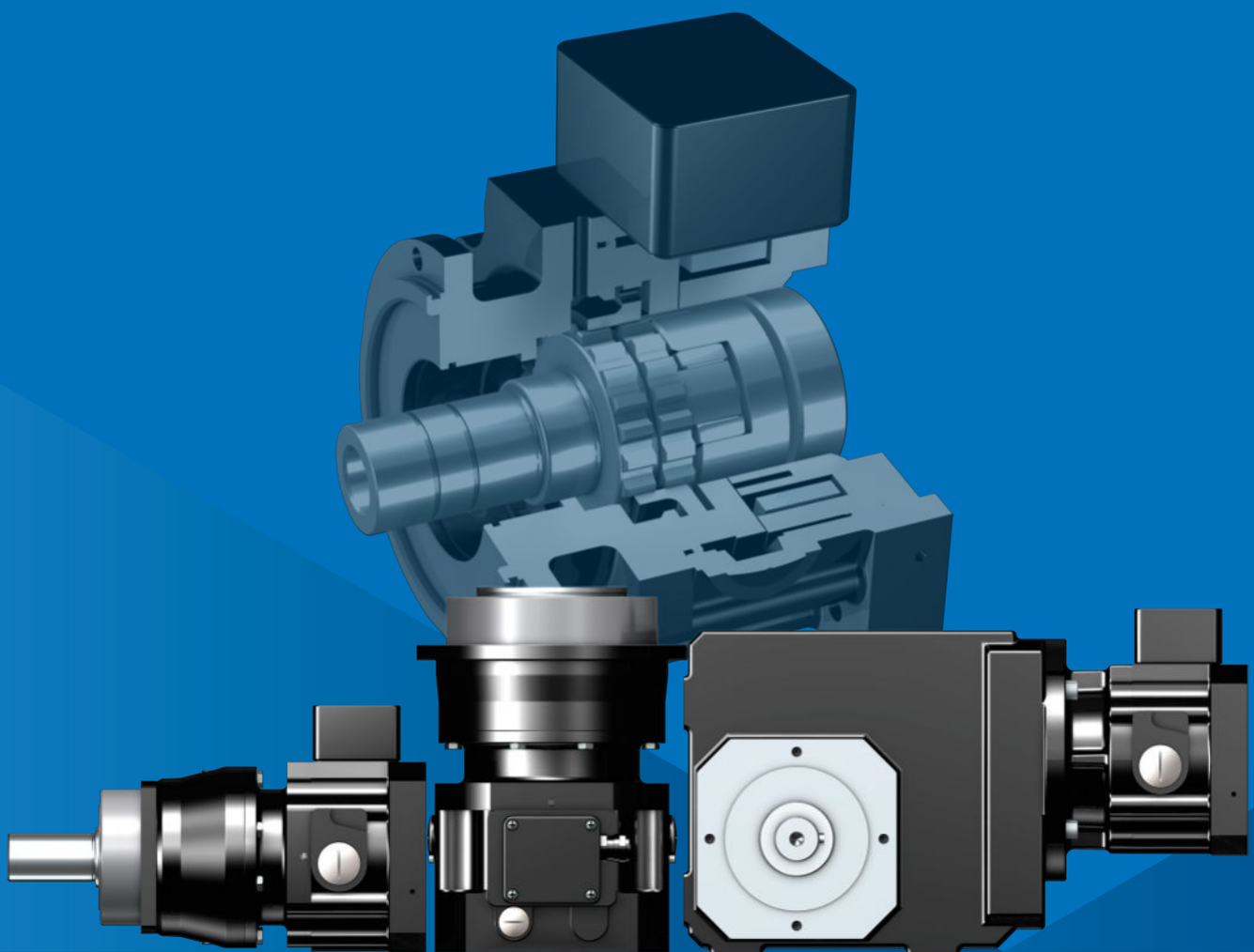


Gravity-loaded axes in the hazard zone

Internal drive selection

STÖBER

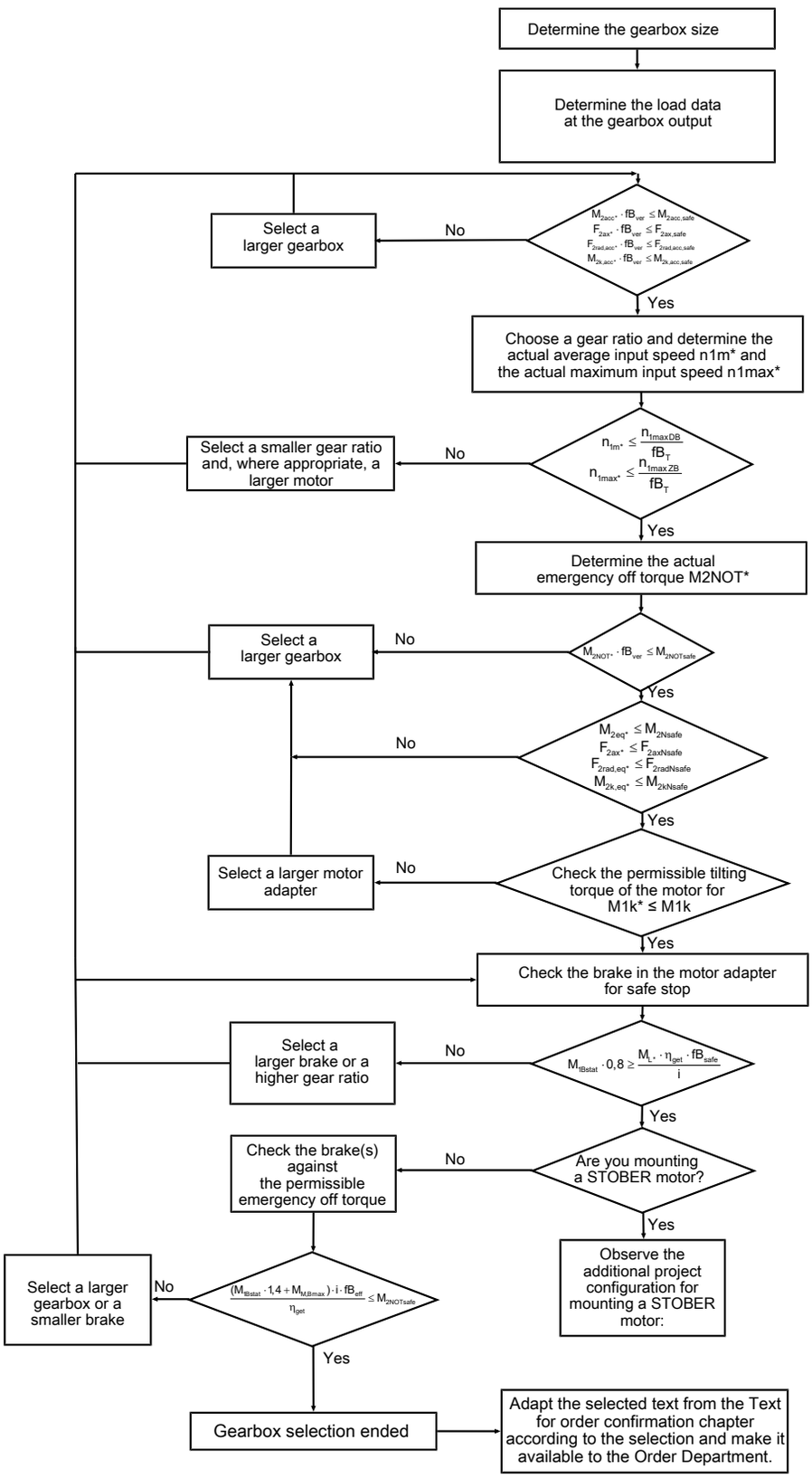
1 Information on this documentation

This documentation helps you safely select drives for gravity-loaded axes in the hazard zone.

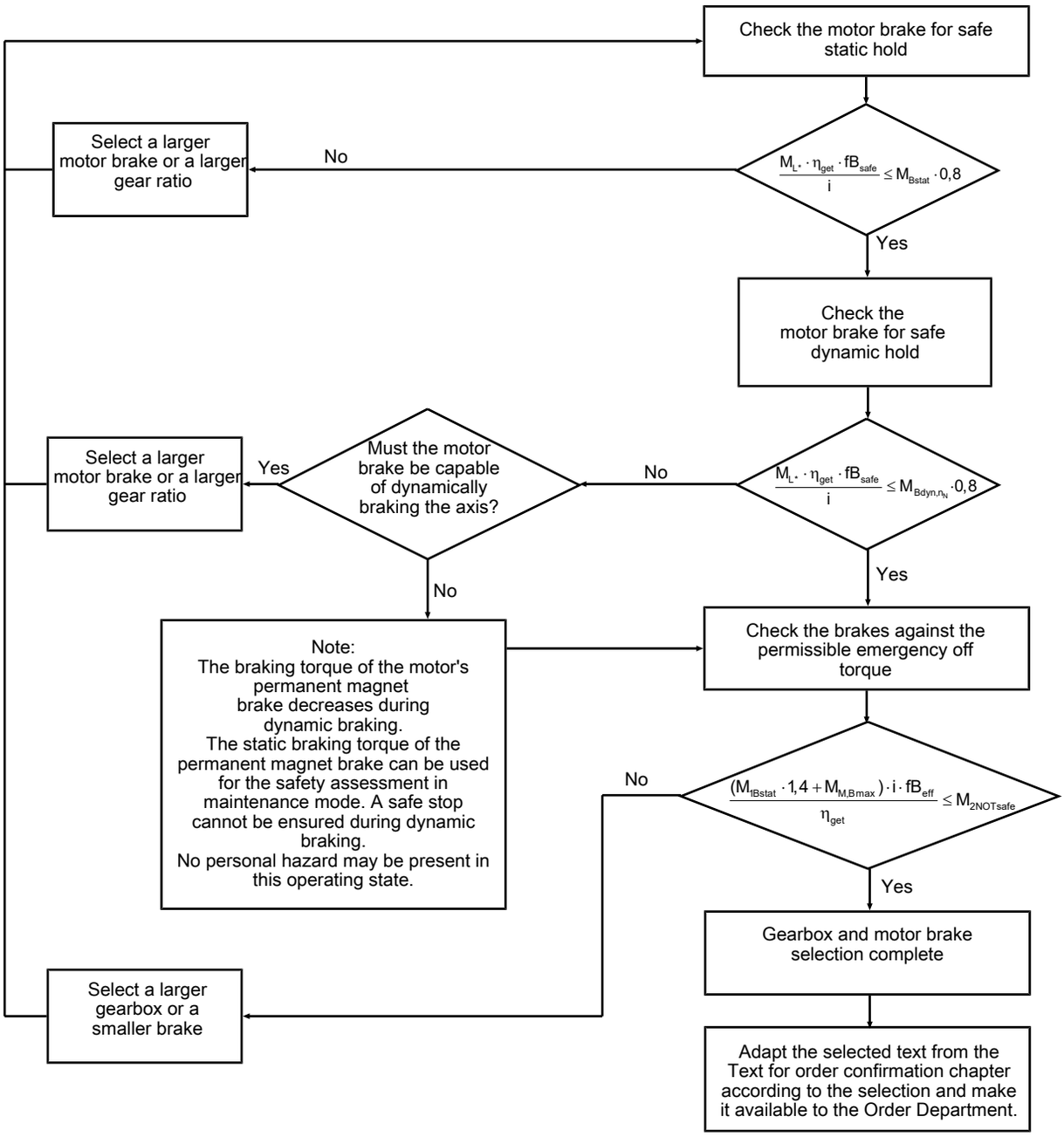
The drive selection refers to DIN EN ISO 16090-1:2019-12, Annex G, and DGUV Fachbereich AKTUELL FBHM-005 (08/2021).

2 Drive selection

The formula symbols for values actually present in the application are marked with *.



Additional project configuration for mounting a STOBER motor:



The values for i, n_{1maxDB}, n_{1maxZB} and M_{1Bstat} can be found in selection tables in the respective chapter of catalog ServoStop servo gearboxes with brake ID 443234_en.

For attaching third-party motors: Refer to the manufacturer catalog for the values for $M_{M,Bmax}$.

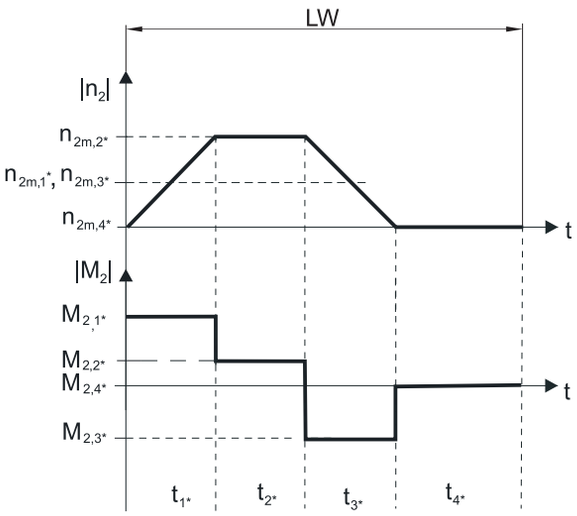
For attaching STOBER motors: Refer to the Motor brake table for the values for $M_{Bdyn,nN}$, $M_{M,Bmax}$ und M_{Bstat}.

For STOBER permanent magnet brakes, a tolerance of −20 % applies to static and dynamic braking torques up to MM,Bmax, for spring-loaded brakes +40 %, −20 %.

The values for fB_T, fB_{safe}, fB_{ver} and fB_{eff} can be found in the corresponding tables in this chapter.

Example of cyclic operation

The following calculations are based on a representation of the power taken from the output based in accordance with the following example:



Calculation of the actual maximum acceleration torque

$$M_{2acc*} = J_{tot} \cdot \frac{\Delta n_2}{9.55 \cdot \Delta t} + M_{L*}$$

Calculation of the actual average input speed

$$n_{1m*} = n_{2m*} \cdot i$$

$$n_{2m*} = \frac{\left|n_{2m,1*}\right| \cdot t_{1*} + \ldots + \left|n_{2m,n*}\right| \cdot t_{n*}}{t_{1*} + \ldots + t_{n*}}$$

If $t_{1*} + \ldots + t_{3*} \geq 6$ min, calculate n_{2m*} without the rest phase t_{4*}.

The values for the ratio i can be found in the selection tables.

Calculation of the actual emergency off torque

$$M_{2NOT*} = J_{tot} \cdot \frac{\Delta n_2}{9.55 \cdot \Delta t} + M_{L*}$$

Calculation of the actual equivalent torque

$$M_{2eq*} = \sqrt[3]{\frac{\left|n_{2m,1*}\right| \cdot t_{1*} \cdot \left|M_{2,1*}{}^3\right| + \ldots + \left|n_{2m,n*}\right| \cdot t_{n*} \cdot \left|M_{2,n*}{}^3\right|}{\left|n_{2m,1*}\right| \cdot t_{1*} + \ldots + \left|n_{2m,n*}\right| \cdot t_{n*}}}$$

Operating factors

Temperature		**fB_T**
Motor cooling	**Surrounding temperature**	
Motor with forced ventilation	≤ 20 °C	0.9
	≤ 30 °C	1.0
	≤ 40 °C	1.15
Motor with convection cooling	≤ 20 °C	1.0
	≤ 30 °C	1.1
	≤ 40 °C	1.25

Safe stop	**fB_{safe}**
Safety-relevant + redundant brake system	≥ 1.00
Safety-relevant + 1 brake	≥ 1.30

Gravity-loaded axes	**fB_{ver}**
Personal hazard → no	≥ 1.00
Personal hazard → yes	≥ 2.00

Safety emergency off	$fB_{NOTsafe}$
Planetary gearboxes	0.6

Mass inertia ratio	fB_{eff}				
Load level	**λ 0.5**	**λ 1**	**λ 2**	**λ 5**	**λ 10**
90	0.92	0.95	0.96	0.98	0.99
75	0.83	0.87	0.91	0.95	0.97
50	0.66	0.75	0.83	0.91	0.95
0	0.33	0.50	0.66	0.83	0.90

$$\text{Load level} = 100 \cdot (1 - \frac{(M_{1Bstat} + M_{M,Bmax^*}) - \frac{M_L \cdot \eta}{i}}{(M_{1Bstat} + M_{M,Bmax^*})})$$

$$\lambda = \frac{J_L}{i^2 \cdot J_1}$$

Motor brake						
Motor type	M_{Bstat} [Nm]	$M_{Bdyn,nN}$ [Nm] 2000 rpm	$M_{Bdyn,nN}$ [Nm] 3000 rpm	$M_{Bdyn,nN}$ [Nm] 4000 rpm	$M_{Bdyn,nN}$ [Nm] 5000 rpm	$M_{M,Bmax}$ [Nm]
EZ202	1.2	–	1.1	–	0.8	3.5
EZ203	1.2	–	1.1	–	0.8	3.5
EZ301	2.5	–	2.5	–	2.3	7.0
EZ302	4.0	–	3.05	–	2.65	7.5
EZ303	4.0	–	3.05	–	2.65	7.5
EZ401	4.0	–	3.05	–	2.65	7.5
EZ402	8.0	–	7.0	–	5.0	14.0
EZ404	8.0	–	7.0	–	5.0	14.0
EZ501	8.0	–	7.0	–	5.0	14.0
EZ502	8.0	–	7.0	–	5.0	14.0
EZ503	15.0	–	12.0	–	8.8	26.0
EZ505	15.0	–	12.0	–	8.8	26.0
EZ701	15.0	–	12.0	–	8.8	26.0
EZ702	15.0	–	12.0	–	8.8	26.0
EZ703	32.0	–	15.9	–	14.0	52.0
EZ705	32.0	–	15.9	–	14.0	52.0
EZ802	65.0	35.0	–	31.0	–	100
EZ803/EZ813	65.0	35.0	–	31.0	–	100
EZ805/EZ815	115	61.0	–	45.0	–	200

Determination of the permitted torques

Calculation of the permissible maximum acceleration torque

$$M_{2acc,safe} = MIN(M_{2verz,sf};M_{2verz,sh};M_{2la,stat};M_{2acc})$$

$M_{2verz,sf}$ for safety factor foot ≥ 1.1

$M_{2verz,sh}$ for safety factor pitting ≥ 1.03

$M_{2la,stat}$ for static load capacity ≥ 1.5 (for ball bearings) and ≥ 2 (for roller bearings)

The values for $M_{2verz,sf}$, $M_{2verz,sh}$ und $M_{2la,stat}$ can be found in the EASY Workbench.

The values for M_{2acc} can be found in catalog ServoStop servo gearboxes with brake ID 443234_en. The M_{2acc} value also includes the shaft-hub connection.

Calculate the values with the maximum occurring torque and the average speed.

Calculation of the permissible nominal torque

$$M_{2Nsafe} = MIN(M_{2L10h};M_{2N})$$

M_{2L10h} bearing service life ≥ 20000 hours (with simple weight force and n1m*).

The values for M_{2L10h} can be found in the EASY Workbench.

The values for M_{2N} can be found in catalog ServoStop servo gearboxes with brake ID 443234_en. The M_{2N} value also includes the shaft-hub connection.

Calculation of the permissible emergency off torque for P, PH, PHQ

$$M_{2NOTsafe} = MIN(2xM_{2acc,safe};M_{2NOT} \cdot 0,9;M_{2zap} \cdot fB_{NOTsafe})$$

Calculation of the permissible emergency off torque for C, F, K, S, PK, PHK, PHQK

$$M_{2NOTsafe} = MIN(2xM_{2acc,safe};M_{2NOT} \cdot 0,9)$$

The value for M_{2zap} (only required for planetary gearboxes) can be found in the EASY Workbench.

The value for $fB_{NOTsafe}$ can be found in the table Safety emergency off in this chapter.

The value for M_{2NOT} can be found in catalog ServoStop servo gearboxes with brake ID 443234_en. The M_{2NOT} value also includes the shaft-hub connection.

Determination of the permitted forces

Determination of the permissible radial acceleration force

$F_{2rad,acc,safe}$ = MIN($F_{2rad,acc}$; $F_{2rad,la,stat}$)

$F_{2rad,acc}$ for safety factor shaft ≥ 1.1

$F_{2rad,la,stat}$ for static load capacity ≥ 1.5 (for ball bearings) and ≥ 2 (for roller bearings)

The value for $F_{2rad,acc}$ can be found in catalog ServoStop servo gearboxes with brake ID 443234_en.

The value for $F_{2rad,la,stat}$ can be found in the EASY Workbench.

Calculation of the permissible axial force

$F_{2ax,safe}$ = MIN(F_{2ax100} bzw. F_{2ax20}; $F_{2ax,la,stat}$)

$F_{2ax,la,stat}$ for static load capacity ≥ 1.5 (for ball bearings) and ≥ 2 (for roller bearings)

The values for F_{2ax100} resp. F_{2ax20} can be found in catalog ServoStop servo gearboxes with brake ID 443234_en.

The value for $F_{2ax,la,stat}$ can be found in the EASY Workbench.

Calculation of the permissible tilting torque

$M_{2k,acc,safe}$ = MIN($M_{2k,acc}$; $M_{2la,stat}$)

$M_{2k,acc}$ for safety factor shaft ≥ 1.1

$M_{2la,stat}$ for static load capacity ≥ 1.5 (for ball bearings) and ≥ 2 (for roller bearings)

The value for $M_{2k,acc}$ can be found in catalog ServoStop servo gearboxes with brake ID 443234_en.

The value for $M_{2la,stat}$ can be found in the EASY Workbench.

Calculation of the permissible nominal radial force

$F_{2radNsafe} = MIN(F_{2rad,acc,safe}; F_{2radL10h})$

$F_{2radL10h}$ bearing service life ≥ 20000 hours (with simple weight force and n_{1m*}).

The value for $F_{2radL10h}$ can be found in the EASY Workbench.

Nominal force must not be higher than acceleration force $F_{2radN,safe} \leq F_{2rad,acc,safe}$

Calculation of the permissible nominal axial force

$F_{2axNsafe} = MIN(F_{2axN}; F_{2axL10h})$

$F_{2axL10h}$ bearing service life ≥ 20000 hours (with simple weight force and n_{1m*}).

The value for F_{2axN} can be found in catalog ServoStop servo gearboxes with brake ID 443234_en.

The value for $F_{2axL10h}$ can be found in the EASY Workbench.

Nominal force must not be higher than permissible axial force $F_{2axNsafe} \leq F_{2ax,safe}$

Calculation of the permissible nominal tilting torque

$M_{2kNsafe} = MIN(M_{2k,acc,safe}; M_{2kL10h})$

M_{2kL10h} bearing service life ≥ 20000 hours (with simple weight force and n_{1m*}).

The value for M_{2kL10h} can be found in the EASY Workbench.

Nominal tilting torque must not be higher than acceleration tilting torque $M_{2kNsafe} \leq M_{2k,acc,safe}$

3 Texts for order confirmation

Example for gravity-loaded axis with radial force/gear:

Maximum permitted load data for one times gravitational force:

Max. permitted acceleration torque at the gearbox output M_{2acc} = 231 Nm

Nominal torque at the gearbox output (relative to n_{1N}) M_{2N} = 182 Nm

Gravitational force = 10010 N (9.81m/s^2 x 1000kg/0.98)

Distance to the force application point x2 = 70 mm

Customer pinion – pitch circle = 150 mm

Customer pinion – helix angle = 0°

The gearbox is designed for static and dynamic loading at twice the gravitational force.

Example for gravity-loaded axis without radial force:

Maximum permitted load data for one times gravitational force:

Max. permitted acceleration torque at the gearbox output M_{2acc} = 231 Nm

Nominal torque at the gearbox output (relative to n_{1N}) M_{2N} = 182 Nm

Gravitational force = 10010 N (9.81m/s^2 x 1000kg/0.98)

No radial or axial forces permitted.

The gearbox is designed for static and dynamic loading at twice the gravitational force.

Text for special case: “Check the brakes against the permitted emergency off torque” condition not met

In the event of an emergency off: The machine is unpowered.

To protect the gearbox, the circuitry must ensure that the two brakes do not engage simultaneously.

Switching sequence: The brake in the motor adapter must engage first. The motor brake must engage after a delay of 500 ms.

Text for failure to achieve the required dynamic braking torque $M_{Bdyn,nN}$:

The braking torque of the motor's permanent magnet brake decreases during dynamic braking The static braking torque of the permanent magnet brake can be used for the safety assessment in maintenance mode. A safe stop cannot be ensured during dynamic braking. No personal hazard may be present in this operating state.

4 Formula symbols

The formula symbols for values actually present in the application are marked with *.

Symbol	Unit	Explanation
Δn_2	rpm	Speed difference at the output
Δt	s	Timespan
η	%	Efficiency
η_{get}	%	Efficiency of the gearbox at nominal torque
F_{2ax*}	N	Actual axial force at the gearbox output
$F_{2ax,la,stat}$	N	Axial force for defined static bearing capacity on the gearbox output
$F_{2ax,safe}$	N	Permissible axial force on the gearbox output for gravity-loaded axes
F_{2ax100}	N	Permitted axial force at the gearbox output for $n_{2m*} \leq 100$ rpm (without radial force)
F_{2ax20}	N	Permitted axial force at the gearbox output for $n_{2m*} \leq 20$ rpm (without radial force)
$F_{2axL10h}$	N	Axial force for defined bearing service life on the gearbox output
F_{2axN}	N	Permitted nominal axial force at the gearbox output (without radial force)
$F_{2axNsafe}$	N	Permitted nominal axial force at the gearbox output (without radial force) for gravity-loaded axes
$F_{2rad,acc}$	N	Permitted radial acceleration force at the gearbox output
$F_{2rad,acc*}$	N	Radial acceleration force present at the gearbox output
$F_{2rad,acc,safe}$	N	Permitted radial acceleration force at the gearbox output for gravity-loaded axes
$F_{2rad,eq*}$	N	Actual equivalent force at the gearbox output
$F_{2rad,la,stat}$	N	Radial force for defined static bearing capacity on the gearbox output
$F_{2radL10h}$	N	Radial force for defined bearing service life on the gearbox output
$F_{2radNsafe}$	N	Permissible nominal radial force on the gearbox output for gravity-loaded axes
fB_{eff}	–	Operating factor mass inertia ratio
$fB_{NOTsafe}$	–	Operating factor safety emergency off
fB_{safe}	–	Operating factor safe stop
fB_T	–	Temperature operating factor
fB_{ver}	–	Operating factor gravity-loaded axes
i	–	Gear ratio
J_1	$kgcm^2$	Mass moment of inertia relative to the gearbox input
J_L	$kgcm^2$	Mass moment of inertia load
J_{tot}	kgm^2	Total mass moment of inertia (based on the motor shaft)
λ	–	Power factor
LW	–	Load change: A load change (LW) corresponds to an acceleration and a deceleration.
M_{1Bstat}	Nm	Static braking torque of the brake in the motor adapter (tolerance +40%, −20%)
M_{1k}	Nm	Permitted tilting torque at the gearbox input
M_{1k*}	Nm	Existing tilting torque on the gearbox input
$\lvert M_2 \rvert$	Nm	Absolute value of torque on the output
$M_{2.1*} – M_{2.4*}$	Nm	Actual torque in the respective time segment (1 to 4)
M_{2acc}	Nm	Maximum permitted acceleration torque on the gearbox output
M_{2acc*}	Nm	Actual acceleration torque on the gearbox output
$M_{2acc,safe}$	Nm	Maximum permitted acceleration torque on the gearbox output for gravity-loaded axes
M_{2eq*}	Nm	Equivalent torque present on the gearbox output
$M_{2k,acc}$	Nm	Permitted acceleration tilting torque at the gearbox output
$M_{2k,acc*}$	Nm	Acceleration tilting torque present at the gearbox output
$M_{2k,acc,safe}$	Nm	Permitted acceleration tilting torque on the gearbox output for gravity-loaded axes
$M_{2k,eq*}$	Nm	Actual equivalent tilting torque on the gearbox output
M_{2kL10h}	Nm	Tilting torque for defined bearing service life on the gearbox output
$M_{2kNsafe}$	Nm	Permitted nominal tilting torque on the gearbox output for gravity-loaded axes
M_{2L10h}	Nm	Torque for defined bearing service life on the gearbox output
$M_{2,n*}$	Nm	Actual torque in the n-th time segment
M_{2N}	Nm	Nominal torque on the gearbox output (relative to n_{1N})
M_{2NOT}	Nm	Gearbox emergency off torque on the gearbox output for max. 1000 load changes
M_{2NOT*}	Nm	Actual emergency off torque for the gearbox on the gearbox output
$M_{2NOTsafe}$	Nm	Gearbox emergency off torque on the gearbox output for max. 1000 load changes for gravity-loaded axes
M_{2Nsafe}	Nm	Nominal torque on the gearbox output (relative to n_{1N}) for gravity-loaded axes
$M_{2la,stat}$	Nm	Torque for defined static bearing capacity on the gearbox output

Symbol	Unit	Explanation
$M_{2verz,sf}$	Nm	Torque for defined safety factor foot on the gearbox output
$M_{2verz,sh}$	Nm	Torque for defined safety factor pitting on the gearbox output
M_{2zap}	Nm	Pin torque on the gearbox output
$M_{Bdyn,nN}$	Nm	Dynamic braking torque at 100 °C and nominal speed
M_{Bstat}	Nm	Static braking torque of the motor brake at 100 °C
M_L	Nm	Load torque
M_{L*}	Nm	Actual load torque
$M_{M,Bmax*}$	Nm	Maximum available motor torque for the gearbox in a redundant brake system including any tolerances of the braking torque
n_{1m*}	rpm	Actual average input speed
n_{1max*}	rpm	Actual maximum input speed
n_{1maxDB}	min^{-1}	Maximum permitted input speed of the gearbox in continuous operation
		(at surrounding temperature of 20 °C)
n_{1maxZB}	min^{-1}	Maximum permitted input speed of the gearbox in cyclic operation
		(at surrounding temperature of 20 °C)
$\lvert n_2 \rvert$	rpm	Absolute value of output speed
n_{2m*}	rpm	Actual average output speed
$n_{2m,1*} – n_{2m,4*}$	rpm	Actual average output speed in the respective time segment (1 to 4)
$n_{2m,n*}$	rpm	Actual average output speed in the n-th time segment
t	s	Time
$t_{1*} – t_{4*}$	s	Duration of the respective time segment (1 to 4)
t_{n*}	s	Duration of the n-th time segment



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