General technical data and calculations

Load on bearing for calculating the service life

Note

In general, the minimum value of 4.0 should not be fallen short of for both the static and dynamic load ratios. In the case of applications that place high demands on rigidity and/or the service life, a higher load ratio is necessary. With tensile loads, check the screw stability. See the chapter entitled “Installation Information”.

Dynamic load ratio $\frac{C}{F_{m,\ max}}$

Static load ratio $\frac{C_0}{F_{eff,\ max}}$

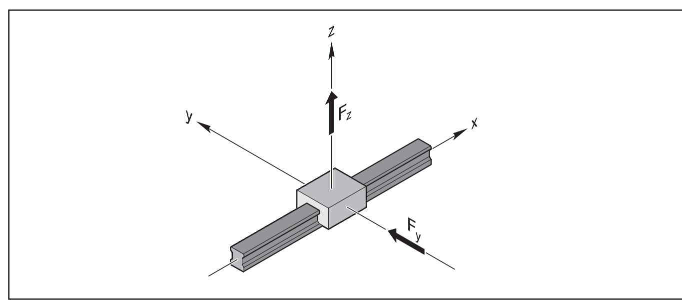
Combined equivalent load

In the case of a combined vertical and horizontal external load, calculate the dynamic equivalent load F_{comb} according to formula (5).

Note

The structure of the ball rail system permits this simplified calculation.

$$F_{comb} = |F_y| + |F_z| \quad (5)$$



Note

Reduce an external load that affects the ball runner block at any angle with the correct sign to F_y and F_z and insert the amounts into formula (5) or (6).

Combined equivalent load in conjunction with moments

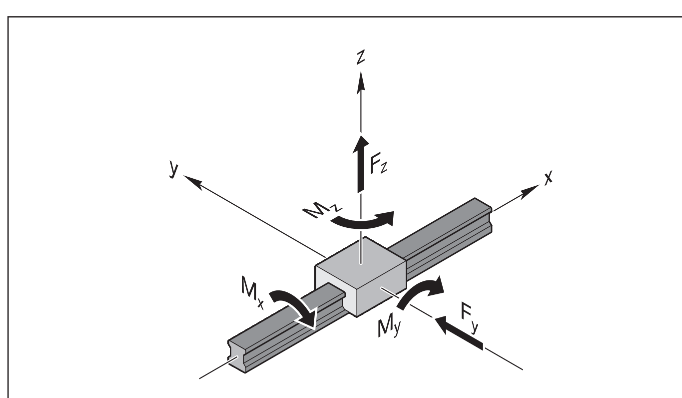
Using formula (6), you can combine all the partial loads that occur in a load case into one single comparison load. i.e. the combined equivalent load.

Notes

Including moments as stated in formula (6) only applies to an individual ball guide rail with just one ball runner block. The formula is simpler for other combinations.

The forces and moments plotted in the coordinate system can also have an effect in the opposite direction. Reduce an external load that affects the ball runner block at any angle to F_y and F_z and insert the amounts into formula (6).
The structural design of the ball runner blocks allows this simplified calculation.

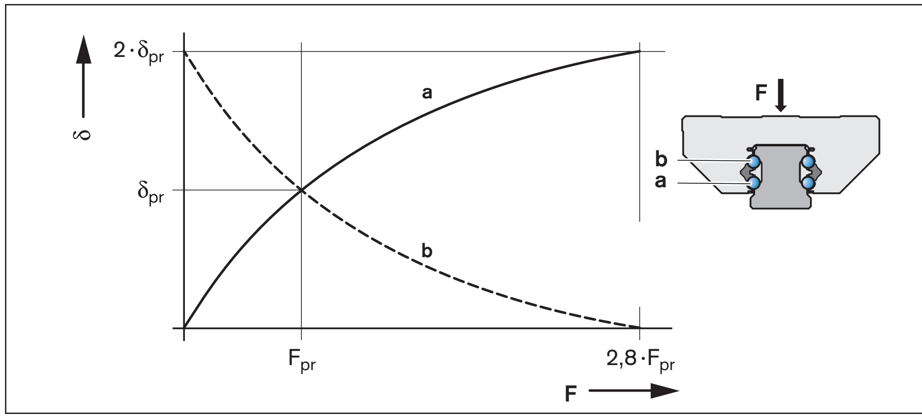
$$F_{comb} = |F_y| + |F_z| + C \cdot \frac{|M_x|}{M_t} + C\,\frac{|M_y|}{M_L} + C \cdot \frac{|M_z|}{M_L} \quad (6)$$



Considering the internal preloading force F_{pr}

To increase the rigidity and precision of the guide system, it is advisable to use preloaded ball runner blocks (c.f. "System Preloading Selection Criterion").

When using ball runner blocks of preload classes C2 and C3, it may be necessary to consider the internal pre-tensioning force; this is because both rows of balls a and b are pretensioned against one another by a specific oversize at an internal pre-tensioning force F_{pr} and deform by the amount δ_{pr} (see the diagram).



a	=	loaded (lower) row of balls	
b	=	non-loaded (upper) row of balls	
δ	=	Deformation of the rolling contact at F	(–)
δ_{pr}	=	Deformation of the rolling contact at F_{pr}	(–)
F	=	load on the ball runner block	(N)
F_{pr}	=	Internal pre-tensioning force	(N)

Effective equivalent load on bearing

From an external load amounting to 2.8 times the internal pre-tensioning force F_{pr} onward, a row of balls becomes preload-free.

Note

Under highly dynamic loading conditions, the combined equivalent load should be $F_{comb} < 2.8 \cdot F_{pr}$ to prevent damage to anti-friction bearings due to slippage.

$$F_{eff} = F_{comb} \qquad (7)$$

Case 1

$F_{comb} > 2.8 \cdot F_{pr}$

In this case, the internal pre-tensioning force F_{pr} does not affect the service life.

$$F_{eff} = \left(\frac{F_{comb}}{2.8 \cdot F_{pr}} + 1\right)^{3/2} \cdot F_{pr} \qquad (8)$$

Case 2

$F_{comb} \leq 2.8 \cdot F_{pr}$

The pre-tensioning force F_{pr} is included in the calculation of the effective equivalent load.

General technical data and calculations

Dynamic equivalent load

With different load stages, calculate the dynamic equivalent load according to formula (9).

$$(9) \quad F_m = \sqrt[3]{(F_{eff\,1})^3 \cdot \frac{q_{s1}}{100\,\%} + (F_{eff\,2})^3 \cdot \frac{q_{s2}}{100\,\%} + \dots + (F_{eff\,n})^3 \cdot \frac{q_{sn}}{100\,\%}}$$

Equivalent static load on bearing

With a combined vertical and horizontal external static load in conjunction with a static torsional or longitudinal moment, calculate the static equivalent load $F_{0\,comb}$ according to formula (10).

$$(10) \qquad F_{0\,comb} = |F_{0y}| + |F_{0z}| + C_0 \cdot \frac{|M_{0x}|}{M_{t0}} + C_0 \cdot \frac{|M_{0y}|}{M_{L0}} + C_0 \cdot \frac{|M_{0z}|}{M_{L0}}$$

Notes

The static equivalent load $F_{0\,comb}$ must not exceed the static load capacity C_0. Formula (10) only applies when using a single ball guide rail.

Reduce an external load that affects the ball runner block at any angle to F_{0y} and F_{0z} and insert the amounts into formula (10).

Definitions and calculation for dynamic and static load ratios

Using the ratio of load capacity to loading of the ball runner blocks, you can make a preselection of the guide. You should choose the dynamic loading ratio C/F_{max} and the static loading ratio $C_0/F_{0\,max}$ to match the application. The necessary load capacities are calculated from this. The load capacity overview yields the corresponding dimensions and format.

Recommended values for load ratios

The table below contains guideline values for the loading ratios.

The values are offered merely as a rough guide reflecting typical customer requirements (e.g. service life, accuracy, rigidity) by sector and application.

$$\text{Dynamic ratio} = \frac{C}{F_{max}}$$

Case 1: Static load $F_{0\,max} > F_{max}$:

$$\text{Static ratio} = \frac{C_0}{F_{0\,max}}$$

Case 2: Static load $F_{0\,max} < F_{max}$:

$$\text{Static ratio} = \frac{C_0}{F_{max}}$$

Machine type/sector	Application example	C/Fmax	$C_0/F_{0\,max}$
Machine tools	**General**	6 ... 9	> 4
	Turning	6 ... 7	> 4
	Milling	6 ... 7	> 4
	Grinding	9 ... 10	> 4
	Engraving	5	> 3
Rubber and plastics processing machinery	**Injection molding**	8	> 2
Woodworking and wood processing machines	**Sawing, milling**	5	> 3
Assembly/handling technology and industrial robots	**Handling**	5	> 3
Oil hydraulics and pneumatics	**Raising/lowering**	6	> 4

Static load safety factor S_0

You must verify mathematically any structural design involving rolling contact with regard to the static load safety factor. The static load safety factor for a linear guide results from the following equation:

$$S_0 = \frac{C_0}{F_{0\,max}}$$

In this connection, $F_{0\,max}$ represents the maximum load amplitude that can occur, which can affect the linear guide. It does not matter whether this load only has an effect for a short time. It may represent a peak amplitude of a dynamic load spectrum. The data in the table applies to size selection.

Conditions of use	Static load safety factor S_0
Overhead hanging arrangements or applications with serious potential risks	≥ 20
High dynamic stress at a standstill, contamination.	8 – 12
Normal design of machines and systems unless all the load parameters or connection accuracies are known.	5 – 8
All the loading data is known. Running free of shocks can be guaranteed.	3 – 5

Legend of formulas

Formula	Unit	Designation
a_1	–	Service life factor
C	N	Dynamic load capacity
C_0	N	Static load capacity
F_{max}	N	Maximum dynamic load
$F_{0\,max}$	N	Maximum static load
F_{comb}	N	Combined equivalent load
$F_{0\,comb}$	N	Equivalent static load on bearing
F_{eff}	N	Effective equivalent load on bearing
$F_{eff\ 1-n}$	N	Uniform effective individual loads
F_m	N	Dynamic equivalent load
F_{pr}	N	Pre-tensioning force
F_y	N	External load due to a resulting force in the Y-direction
F_{0y}	N	External load due to a static force in the Y-direction
F_z	N	External load due to a resulting force in the Z-direction
F_{0z}	N	External load due to a static force in the Z-direction
M_t	Nm	Dynamic torsional moment load capacity[1)]
M_{t0}	Nm	Static torsional moment load capacity[1)]
M_L	Nm	Dynamic longitudinal moment load[1)]
M_{L0}	Nm	Static longitudinal moment load[1)]
M_x	Nm	Load due to the resulting moment around the X-axis
M_{0x}	Nm	Load due to the static moment around the X-axis

Formula	Unit	Designation
M_y	Nm	Load due to the resulting moment around the Y-axis
M_{0y}	Nm	Load due to the static moment around the Y-axis
M_z	Nm	Load due to the resulting moment around the Z-axis
M_{0z}	Nm	Load due to the static moment around the Z-axis
L_{10}	m	Nominal life (travel range)
$L_{h\,10}$	h	Nominal life (time)
L_{na}	m	Modified nominal life (travel range)
L_{ha}	h	Modified nominal life (time)
n	RPM	Stroke repetition rate (double strokes)
s	m	Stroke length
S_0	–	Static load safety factor
v_m	m/min	Average linear speed
$v_1 \dots v_n$	m/min	Travel speeds of phases 1 ... n
$q_{t1} \dots q_{tn}$	%	Discrete time steps for $v_1 \dots v_n$ of phases 1 ... n
Refer to the table for the values		