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1.1 UNITS AND DEFINITIONS

B	mm	Guideway width
B1	mm	Cage width
b	mm	Distance between guidance system centres
b1	mm	Distance between rear guideway surfaces
C	N	Basic dynamic load rating for cage length of 100 mm
C_w	N	Effective dynamic load rating
C_{we}	N	Corrected effective dynamic load rating
C_L	N/mm	Rigidity of the flat cage guidance system
C_0	N	Basic static load rating for cage length of 100 mm
C_{0we}	N	Corrected effective static load rating
C_{0w}	N	Effective static load rating
D_w	mm	Ball diameter
e	mm	Eccentricity of the load
f_H	-	Dynamic hardness factor
f_{H0}	-	Static hardness factor
f_α	-	Dynamic load direction factor
$f_{\alpha 0}$	-	Static load direction factor
F	N	Operating load, guide loading
F_i	N	Variable load
F_R	N	Displacement resistance
F_{R0}	N	F_R, lubricant friction percentage
F_{R1}	N	F_R, load-dependent rolling friction percentage
F_{RA}	N	Displacement resistance, wiper percentage
F_{RV}	N	Carriage displacement resistance, preloaded
F_w	N	Limiting load for effective cage length
H	mm	Distance from extreme stroke positions
k_F	-	Dynamic load factor
k_{0F}	-	Static load factor
K	-	Type factor for determination of rigidity

L	mm	Guideway length
L	10^5m	Nominal rating life
L1	mm	Distance between the first hole and the start of the guideway
L1	mm	Distance between the first or last pocket centre and the end of the cage
L2	mm	Distance between the last hole and the end of the guideway
L1, L2$_{min}$	mm	Minimum value for L1 and L2
LA	mm	Hole distance in guideways
LA	mm	Spacing distance in flat cages
L_h	h	Nominal rating life in operating hours
L_K	mm	Cage length
L_R	mm	Guideway length with running surface for the wiper
n	-	Maximum possible number of hole distances LA
n_{osz}	min^{-1}	Number of double strokes per minute
p	-	Rating life exponent
p	N/mm^2	Contact pressure for sliding layer
P	N	Dynamic equivalent load
P_0	N	Static equivalent load
q_i	%	Proportion of total duration
RS	N	Damping force in direction of movement
S_0	-	Static load safety factor
t	mm	Depth of thread in T03 holes
v_i	m/min	Variable speed
$\bar{v}$	m/min	Dynamic equivalent speed
x	-	Number of holes
Z	-	Number of rolling elements per row
α	°	Load direction angle deviating from main load direction
δ	μm	Elastic deformation at contact points
μ	-	Friction coefficient
ν	mm^{2}s^{-1}	Kinematic viscosity
Δh	μm	Permissible height variation

1.2 PRECISION AND TOLERANCES

1.2.1 QUALITIES

The raceways and locating surfaces are precision-ground.

The guideways are supplied in 3 qualities (parallelism tolerance of the raceways to the reference sides of the guideway in relation to a defined length).

Q10: normal quality for general machine construction
Q6:   precise quality for machine tool construction
Q2:   particularly precise quality for exceptionally demanding structures
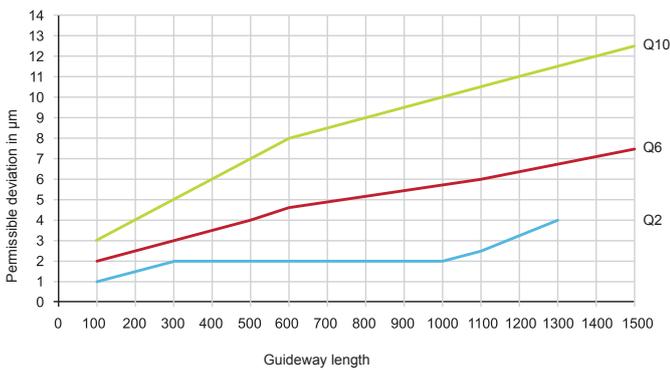
1.2.2 PROFILE TOLERANCES

See product chapter

1.2.3 LENGTHS, HOLE DISTANCES

Length: the length tolerance is defined using the formula ± [0.2+(0.0012* length L)].

Guideways which exceed the maximum length indicated (see "normal lengths" table) are manufactured in several sections. These sections are matched precisely. It is important not to interchange the guideways in order to maintain the tolerance during assembly.

Hole distances: the tolerance of the hole distances is calculated to ensure that guideways can be assembled on a pre-drilled hole pattern up to the maximum normal length. The tolerance is measured between the first and last guideway hole and is distributed evenly over the length.

For guideways which exceed the maximum normal length, the suffix "P" is required in order to maintain the corresponding tolerance.
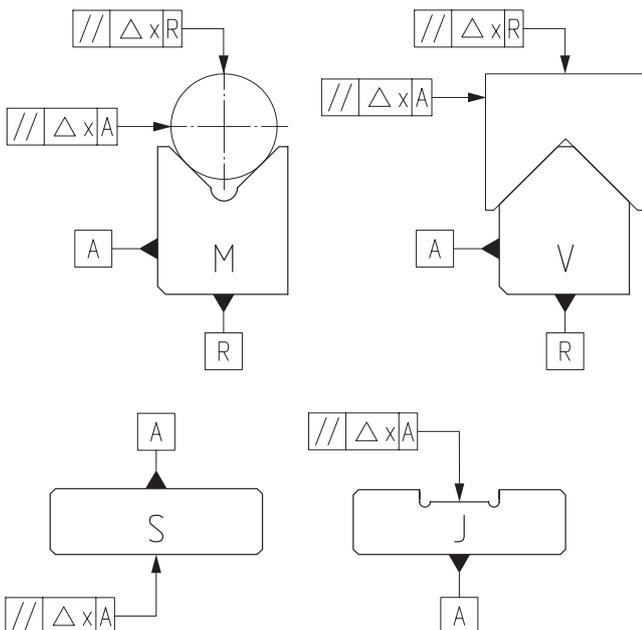
1.2.4 MATCHING

Guideways of the same design (same order reference) are manufactured, labelled and packed in pairs. Paired matching is based on the distance between the centre of the profile and the mounting surface "A".

Standard matching (US1/US2) allows parts to be exchanged whilst maintaining a very narrow tolerance. In the highest tolerance category or at the customer's request, the guideways are matched and labelled by more narrow tolerances.
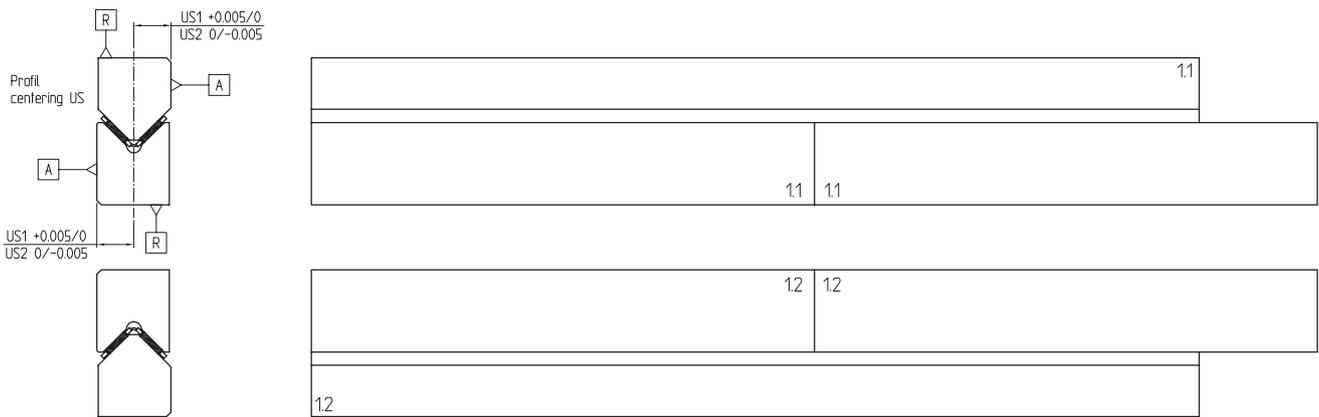
For guideways with different order references which still have to be matched in pairs, the suffix "X" has to be added to the order references, e.g.

1M + 1ML = 2SX or
1M + 1V + 1J + 1S = 4SRX or
1V…T15 + 1V…T03 = 2SX

Matching possibilities:
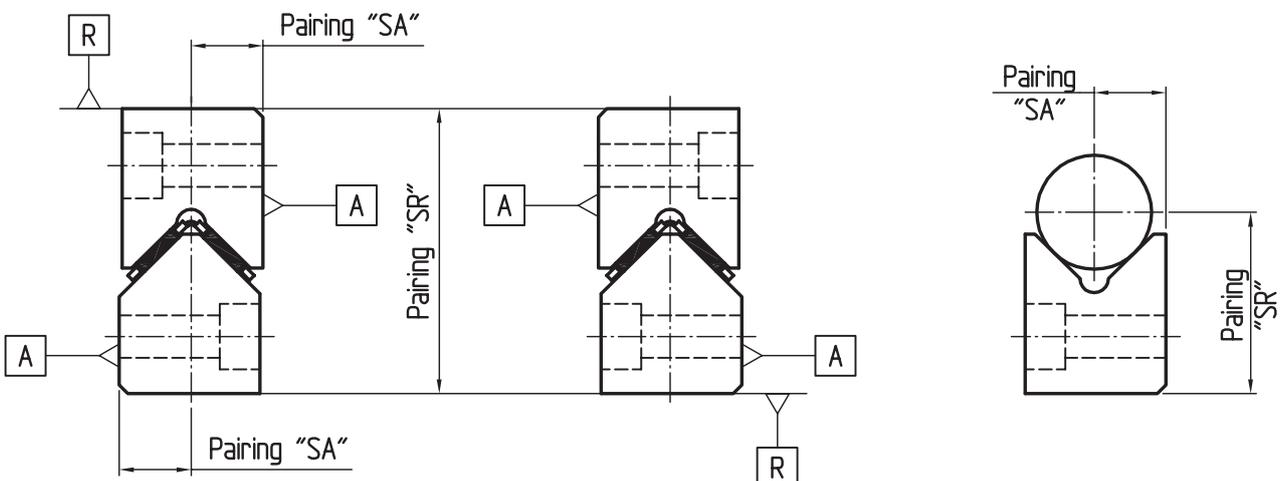
Paired matching code	Number of guideways matched together	In relation to reference side
2SA	2	Reference side A
3SA	3	Reference side A
4SA	4	Reference side A
etc…	Number of guideways	Reference side A
2SR	2	Reference side R
3SR	3	Reference side R
4SR	4	Reference side R
etc…	Number of guideways	Reference side R
2SAR	2	Reference sides A + R
3SAR	3	Reference sides A + R
4SAR	4	Reference sides A + R
etc…	Number of guideways	Reference sides A + R

1.2.5 STRAIGHTNESS

Straightness as well as parallelism is checked in the factory (tolerances according to DIN 644).

Straightness variances can be balanced out by tightening against the locating surface during assembly.

1.2.6 ROLLING ELEMENTS

Flat cage assemblies comprise needle or cylindrical rollers with a diameter tolerance of 2 µm and a geometrical accuracy of 1 µm.

For particularly challenging requirements, especially for guideways with a quality level of 2, specially designed needle or cylindrical rollers can be supplied with a diameter tolerance of 1 µm and a geometrical accuracy of 0.5 µm.

The diameter tolerance amounts to 1 µm and the geometrical accuracy 0.13 µm for ball bearings.

See table (page 76), in chapter 8 on flat cage assemblies.

1.3 APPLICATION FEATURES

1.3.1 CHOICE OF ARRANGEMENT TYPE

Closed layout M/V

This layout can carry loads and moments in any direction, can be adapted to any operating position and can be preloaded (preloading page 34).

It is a locating/locating bearing and consists of two M / ML and two V guideways with the corresponding angled flat cage assemblies.
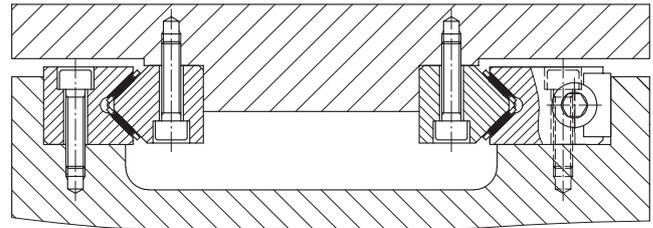
Figure 1. Closed layout M/V

Open layout

This layout is extremely assembly-friendly and is mainly used for applications with loads acting centrically or vertically.

It is a locating/non-locating bearing and consists of M and V guideways with the corresponding angled flat cage assembly and J and S guideways with the corresponding flat cage assembly.
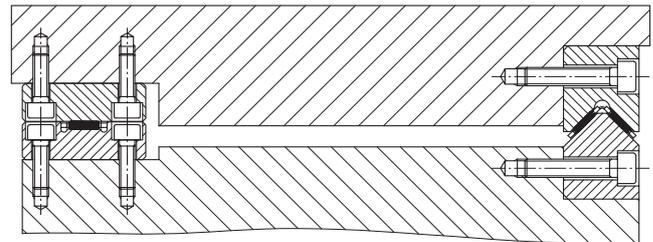
Figure 2. Open layout M/V, J/S

Closed layout LUE

This layout can carry loads and moments in any direction in response to the most demanding precisions requirements. The system is preloaded by components which have been adjusted against one another in terms of dimensions.

The subdivision into locating and non-locating bearings prevents the system from becoming distorted by thermal expansion. The guidance system consists of M and V guideways, J and S guideways, LU counterstays, angled flat and flat cage assemblies.
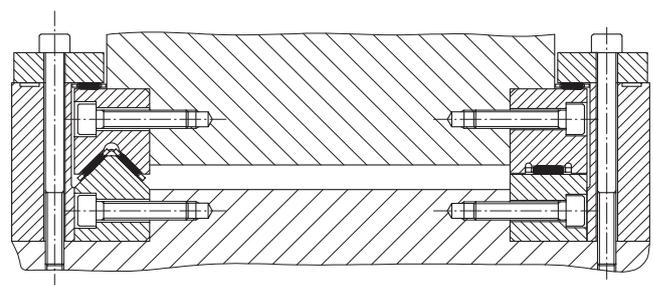
Figure 3. Closed layout LUE

1.3.2 DETERMINATION OF GUIDEWAY CAGE LENGTHS

The rigidity and load carrying capacity of the guidance system are determined by the size and length of the flat cage assembly (L_K). The load bearing capacity and load carrying capacity increase for moments along the longitudinal axis (rolling) in proportion to the cage length whilst the permissible moments along the vertical axis (yawing) and the diagonal axis (pitching) increase in square with the cage length.

Layout principles:
– The cage assembly always travels half of the stroke of the moving guideway
– The entire length of the cage assembly must always remain between the two guideways
– Wipers must always remain on the raceways

Recommendations for minimum cage lengths dependent on the stroke:

$L_K \geq 1.5 \cdot H$ for open layout in order to maintain the operation limit (figure 12, page 26)

$L_K \geq H$ for closed layout

| **H** | **mm** | distance from extreme stroke positions |

A) Calculation of guideway lengths L, L_R
With preset cage length and stroke:

Guidance systems without wipers

$$L = L_K + \frac{H}{2}$$

Guidance systems with wipers

$$L_R = L_K + 3 \cdot \frac{H}{2} + 10$$
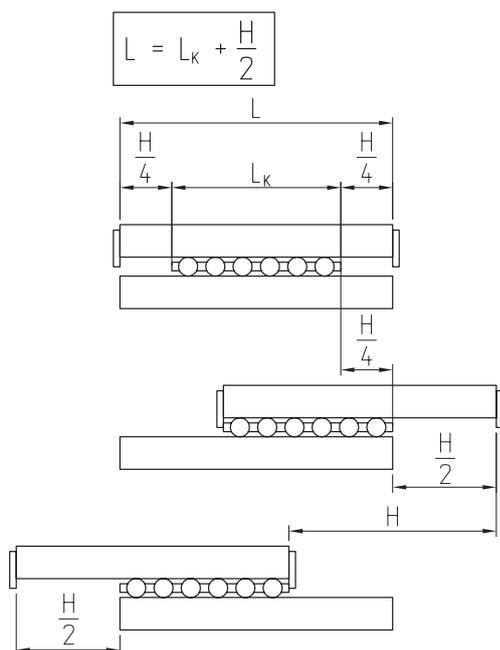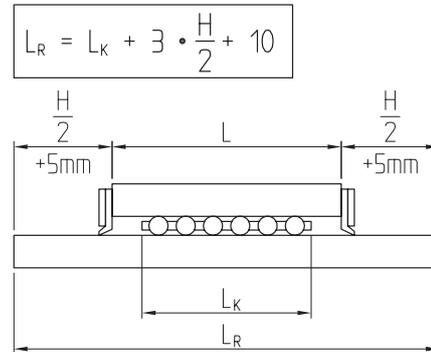
B) Calculation of cage length L_K
With preset guideway lengths and stroke:

Guidance systems without wipers

$$L_K = L - \frac{H}{2}$$

Guidance systems with wipers:

$$L_K = L_R - 3 \cdot \frac{H}{2} - 10$$
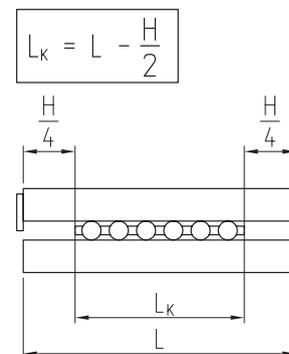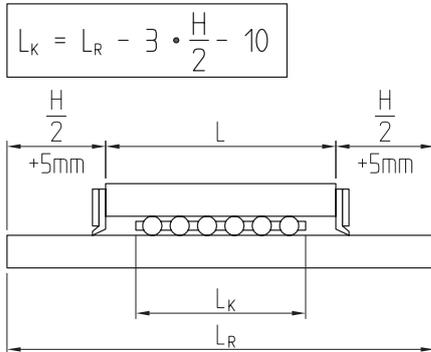
The necessary cage size can be selected on the basis of load and rigidity parameters.

Special length ratios:

If the lengths are configured according to the equations above, the flat cage assembly will be in every stroke position between the raceways.

In order to achieve the maximum load carrying capacity or a significant stroke, the lengths can be configured under normal operating conditions in such a way that the flat cage assembly extends beyond the ends of the guideways. Raceway lead areas should be provided in this case (suffix E2).

1.3.3 HOLE TYPES AND HOLE PATTERNS

Guideways are attached with screws. EGIS guideways are supplied with 4 hole types (figure 4).

EGIS guideways of standard lengths in the M and V ranges are hardened and pre-ground with T15 sink holes. By adding ESM insert nuts, these guideways can be attached in the same manner as with a threaded hole (T03, figure 5).

The insert nuts must be ordered separately and stuck into the counterbores (T13, accessories, page 91).
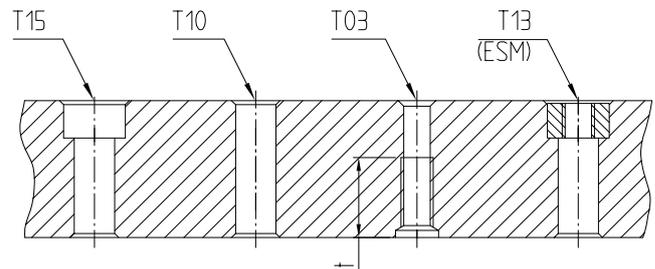
Figure 4. Hole types
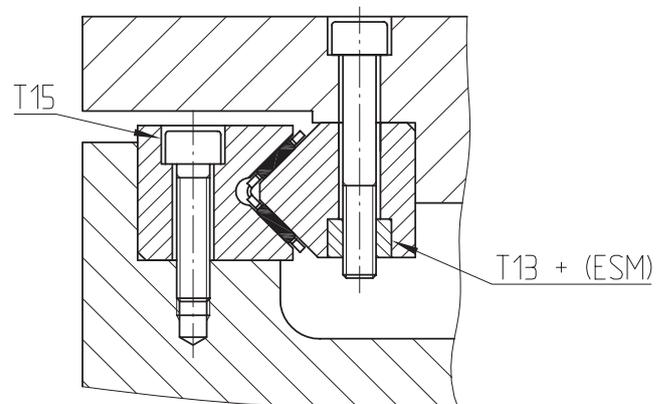
Figure 5. Attachment with hole type T13

With no particular specifications, the hole distances L1 and L2 at both ends of the guideways are of the same size and dependent on the guideway length (symmetrical hole pattern, figure 6).

Guideways with non-symmetrical hole patterns may also be supplied on request.

In this case the following values must apply: $L1 \geq L1_{min}$ and $L2 \geq L2_{min}$.

△ Particular attention should be paid to the position of the L1 distance. For the definition of the position of L1 see figure 7.

Suffix LA (L1/L2)

Determining the hole patterns

Number of spacing distances

$$n = \frac{(L - 2 \cdot L1_{min})}{LA} \quad \text{whole number}$$

Distances L1 and L2

$$L1 + L2 = L - n \cdot LA$$

Guideways with symmetrical hole pattern

$$L1 = L2 = (L - n \cdot LA)/2$$

Number of holes

$$x = n + 1$$

L	**mm**	Length of guideway
LA	**mm**	Hole distance
L1, L2	**mm**	Distance between the start or end of the guideway and the next hole
L1$_{min}$, L2$_{min}$	**mm**	Minimum value for L1 and L2 (Tables dimensions)
n	**-**	Maximum possible spacing distances
x	**-**	Number of holes
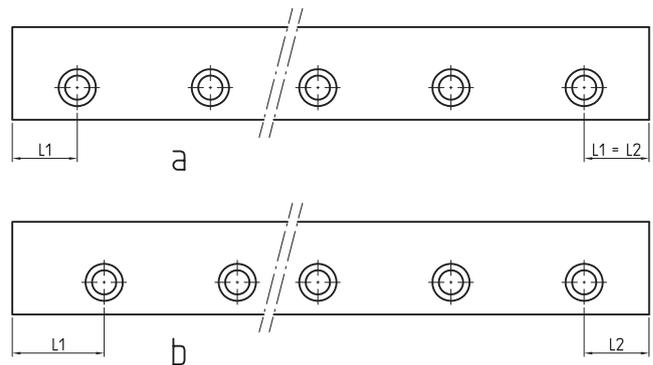
Figure 6. Symmetrical (a) and non-symmetrical (b) hole pattern with a series of holes
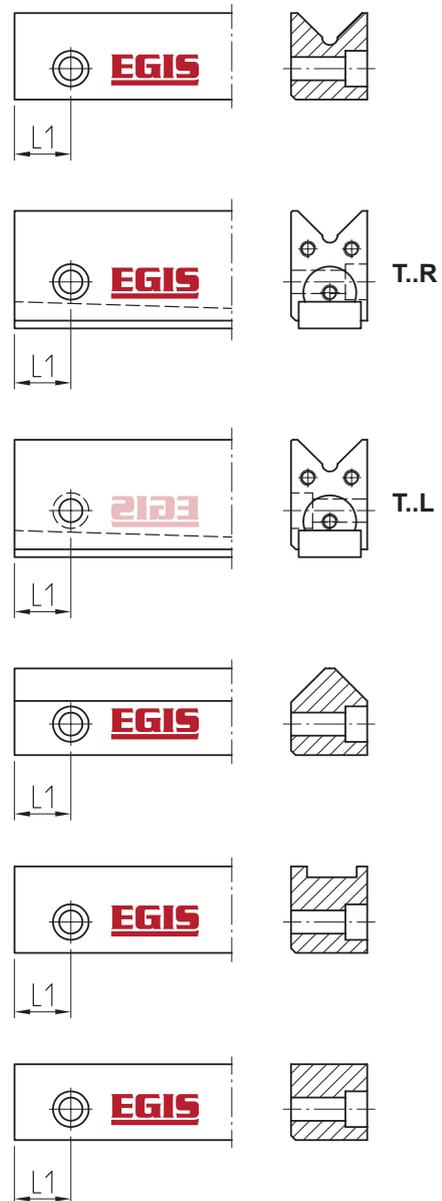
Figure 7. Position of distance between first hole and beginning of guideway L1

1.3.4 END PIECES AND WIPERS

End pieces or end pieces with wipers hold the cage as-
sembly in place correctly in the final stroke positions. Two
end pieces need to be mounted for each cage. If this is
not possible, parts of the connecting structure should be
used to assume the function of the end pieces.

△ End pieces or wipers must not be used
   to limit the stroke.

△ End pieces or wipers must not be allowed
   to cross over (figure 8)

In specific application scenarios, e.g. with rapid accel-
erations, extreme loads in the final stroke positions or in
the case of alternating partial stroke which nevertheless
remain constant over long periods, the cage positioning
may no longer be guaranteed with normal end pieces.
In such cases, it is possible when wipers are used to
assemble additional end pieces before the wipers or
to subject the cage to positive control by an integrated
gear/toothed rack unit as an optimum solution (MVZ
series, page 54).
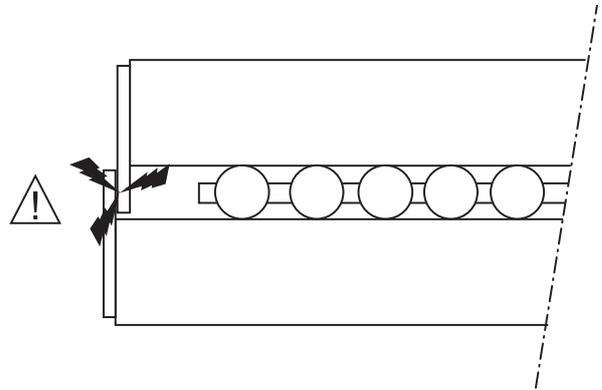
Figure 8. Incorrectly assembled end pieces or wipers

1.3.5 LOAD RATING, LOAD CARRYING CAPACITY

The dynamic and static load ratings are used as a reference for the layout of a flat cage guidance system. The load ratings for linear guidance systems without recirculating rolling elements are defined according to the ISO 14728 international standard.

1.3.5.1 BASIC STATIC LOAD RATING

The basic static load ratings C_0 are the loads which bring a permanent deformation of the raceways and rolling elements in a ten thousandth of the rolling element diameter.

Static load safety factor

The static load safety factor S_0 is the security in relation to the permanent deformation in the rolling contact.

$$S_0 = \frac{C_{0w}}{P_0}$$

S_0		Static load safety factor
C_{0w}	N	Effective static load rating (page 24)
P_0	N	Maximum static equivalent load

△ Particular attention should be paid to the load safety factor.

According to ISO 14728, the static safety $S_0 = C_0/P_0$ must not fall below the value of 2.

If strict requirements apply in terms of the running accuracy and smoothness, the static load safety factor should not fall below $S_0 = 3$.

1.3.5.2 STATIC LOAD CARRYING CAPACITY

The permissible static load for a flat case guidance system is limited by the following characteristics:

– Basic static load rating of the flat cage assemblies: recommendations for S_0 should be observed.

– Load carrying capacity of the raceways: required hardness HRC 58 min.

– Load carrying capacity of the connecting structure: the connecting structure is generally configured with a high degree of rigidity and therefore sufficient strength.

– Load carrying capacity of the screw connection: the layout of the guideway attachment is based on the screw strength 8.8 and the corresponding tightening torque taking the standard materials for the connecting structure into account. Screws of this level of strength allow for the transferral of loads whilst scarcely affecting the precision of the guidance system.

When screws of a higher strength category are used, the tightening torque according to the strength category 8.8 should not be exceeded in the interest of accuracy (exception: LUE system counterstay, see page 73).

△ It is important to check the screw connection where $S_0 < 3$ when tensile and / or moment loads are predominant.

LOAD RATING, LOAD CARRYING CAPACITY

1.3.5.3 BASIC DYNAMIC LOAD RATING

The basis for the basic dynamic load rating C is the nominal rating life of 100,000 m displacement distance obtained or exceeded with a reliability of 90%.

1.3.5.4 DYNAMIC LOAD CARRYING CAPACITY AND RATING LIFE

The dynamic load carrying capacity is determined by the fatigue behaviour of the bearing components. The fatigue period (the rating life in hours) is obtained from the load and the movement speed of the guidance system as well as the statistical probability of damage occurring.

Nominal rating life

$$L = \left(\frac{C_w}{P}\right)^p$$

$$L_h = \frac{8.33 \cdot 10^5}{H \cdot n_{osz}} \cdot \left(\frac{C_w}{P}\right)^p$$

$$L_h = \frac{1666}{\bar{v}} \cdot \left(\frac{C_w}{P}\right)^p$$

L	**10^5 m**	Nominal rating life
L_h	**h**	Nominal rating life in operating hours
C_w	**N**	Effective dynamic load rating (p. 24)
P	**N**	Dynamic equivalent load
p	**-**	Rating life exponent
		For flat cage guidance systems with rollers: p=10/3 For flat cage guidance systems with balls: p=3
H	**mm**	Distance from extreme stroke positions
n_{osz}	**min^{-1}**	Number of double strokes per minute
$\bar{v}$	**m/min**	Dynamic equivalent speed

△ According to ISO 14728, the dynamic equivalent load must not exceed the value $P = 0.5 \cdot C_W$.

LOAD RATING, LOAD CARRYING CAPACITY

Equivalent load and speed

The life calculation equation require a constant load and speed. If this is not the case, equivalent operating values may be used for the calculation.
(ISO 281 standard)

General dynamic equivalent load

$$P = \sqrt[p]{\left(\int_{O}^{T}|v(t)\cdot F^{P}(t)|dt\right) \Big/ \left(\int_{O}^{T}|v(t)|dt\right)}$$

General dynamic equivalent speed

$$\bar{v} = \frac{1}{T}\int_{O}^{T}|v(t)|dt$$

Gradually alternating load

$$P = \sqrt[p]{\frac{q_1\cdot F_1^p + q_2\cdot F_2^p + ... + q_2\cdot F_z^p}{100}}$$

Gradually alternating speed

$$\bar{v} = \frac{q_1\cdot v_1 + q_2\cdot v_2 + ... + q_z\cdot v_z}{100}$$

Gradually alternating load and gradually alternating speed

$$P = \sqrt[p]{\frac{q_1\cdot v_1 + F_1^p\cdot q_2\cdot v_2\cdot F_2^p + ... + q_2\cdot v_z\cdot F_z^p}{q_1\cdot v_1 + q_2\cdot v_2 + ... + q_2\cdot v_z}}$$

P	**N**	Dynamic equivalent load
p	**-**	Rating life exponent:

For flat cage guidance systems with rollers: p=10/3
For flat cage guidance systems with balls: p=3

q_i	**%**	Proportion of total duration
F_i	**N**	Variable load
v_i	**m/min**	Variable speed
$\bar{v}$	**m/min**	Dynamic equivalent speed

Operating life

The operating life is the actual expected rating life of a flat cage guidance system. It may differ from the nominal rating life.

Potential causes include wear and tear and/or fatigue due to:
– Soiling
– Insufficient lubrication
– Misalignment
– Movements with minimal strokes
– Vibrations during dead time (false brinelling).

The operating life of a flat cage guidance system cannot be calculated precisely in advance due to the wide range of installation and operating conditions. The most reliable information is obtained from comparisons with similar installations.

1.3.5.5 EFFECTIVE LOAD RATING

The basic dynamic and static load ratings C and C_0 given for the different products relate to a cage with a theoretical length of 100 mm. This allows direct comparisons to be made between the load carrying capacities of flat cages of different series and dimensions. The effective dynamic and static load ratings C_w and C_{0w} are calculated according to the following equations for the effective cage lengths.

For needle roller flat cage assemblies:

$$C_w = C \cdot \left(\frac{L_K - 2L1 + LA}{100} \right)^{\frac{3}{4}} \cdot \left(\frac{L_K - 2L1}{100 - LA} \right)^{\frac{1}{36}}$$

$$C_{0w} = C_0 \cdot \left(\frac{L_K - 2L1 + LA}{100} \right)$$

For ball flat cage assemblies:

$$C_w = C \cdot \left(\frac{L_K - 2L1 + LA}{100} \right)^{\frac{2}{3}} \cdot \left(\frac{L_K - 2L1}{100 - LA} \right)^{\frac{1}{36}}$$

$$C_{0w} = C_0 \cdot \left(\frac{L_K - 2L1 + LA}{100} \right)$$

C	**N**	Basic dynamic load rating for a cage length of 100 mm (table dimensions)
C_0	**N**	Basic static load rating for a cage length of 100 mm (table dimensions)
C_w	**N**	Effective dynamic load rating
C_{0w}	**N**	Effective static load rating
L_K	**mm**	Cage length (figure 9)
L1	**mm**	Distance between the first and last pocket centre and the end of the cage (figure 9)
LA	**mm**	Spacing distance in the flat cage (figure 9, table dimensions)

The values for C_{0w} and C_w correspond to the load rating calculation according to ISO 14728

⚠ The equations only provide precise results when the cage length Lk is based on a whole number of rolling elements per row.

Equation for verification of Z:

$$Z = \frac{L_K - 2L1}{LA} + 1 = \text{whole number}$$

Z - number of rolling elements per row (figure 9)
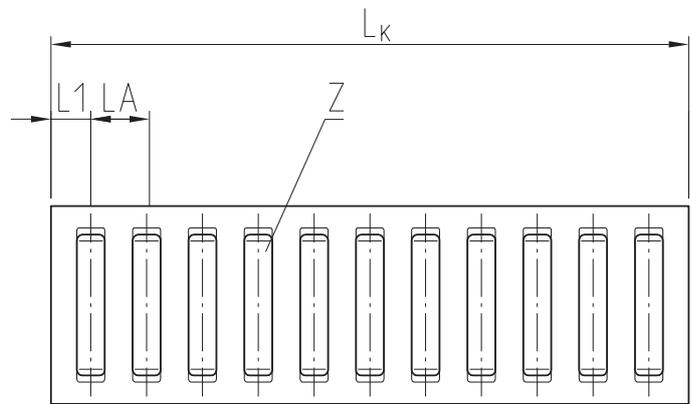
Figure 9. Dimensions to determine the effective load rating

1.3.5.6 CORRECTION FACTORS FOR LOAD CARRYING CAPACITY

The basic load ratings given for the different products only apply subject to the following requirements:

– Raceway hardness ≥ HRC 58 (670HV)

– Centric load direction

Deviating conditions are to be taken into account using the following correction factors:

– Hardness factors f_{H0} or f_H
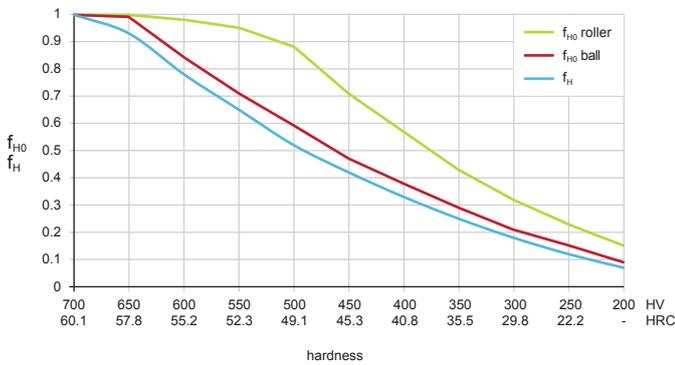
Figure 10. Hardness factors

– Load direction factor f_α or $f_{\alpha 0}$
The basic load ratings for the different products only apply provided that the load operates in symmetry with the cage shanks ($\alpha = 0°$). The correction factor for other load directions can be obtained from the figure:
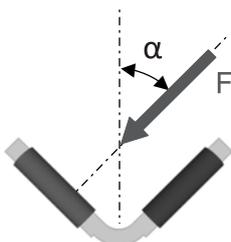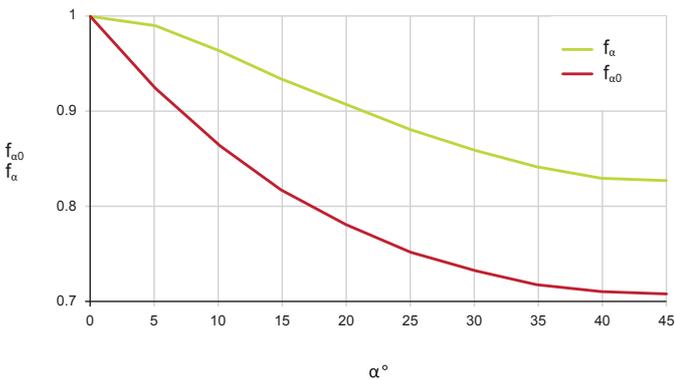
Figure 11. Load direction factor

Static load rating

$$C_{0we} = f_{\alpha 0} \cdot f_{H0} \cdot C_{0w}$$

C_{0we}	**N**	Corrected effective static load rating
$f_{\alpha 0}$	**-**	Static load direction factor
f_{H0}	**-**	Static hardness factor
C_{0w}	**N**	Static load rating for the effective cage length

Dynamic load rating

$$C_{we} = f_\alpha \cdot f_H \cdot C_w$$

C_{we}	**N**	Corrected effective dynamic load rating
f_α	**-**	Dynamic load direction factor
f_H	**-**	Dynamic hardness factor
C_w	**N**	Dynamic load rating for the effective cage length

1.3.5.7 ECCENTRIC LOAD

In a linear guidance system without recirculating rolling elements, the flat cage always travels half the stroke of the mobile guideway and thus alters its position in relation to the load. It therefore does not generally carry an equal load. However, the load ratings given for the different products only apply with an equal load distribution.

Eccentric load with open layout

Open layout: see application features (page 16, figure 2) In the case of an eccentric load, the load carrying capacity can be determined with the static equivalent cage load (figure 12).

$$P_0 = k_{0F} \cdot F$$

P_0	N	Static equivalent load
k_{0F}	-	Static load factor
F	N	Guide loading

Eccentric load with closed layout

Closed layout: see application features, (page 16, figure 1)

Linear guidance systems with a closed layout can carry additional loads and tilting moments. In these cases, the calculation of the equivalent cage load is fairly complex. EGIS offers support with corresponding calculation programmes on request (pages 28 to 31).
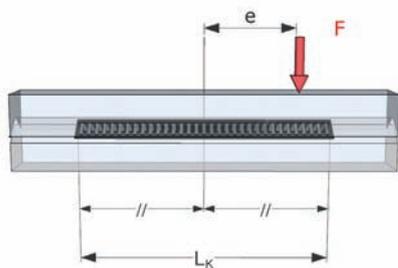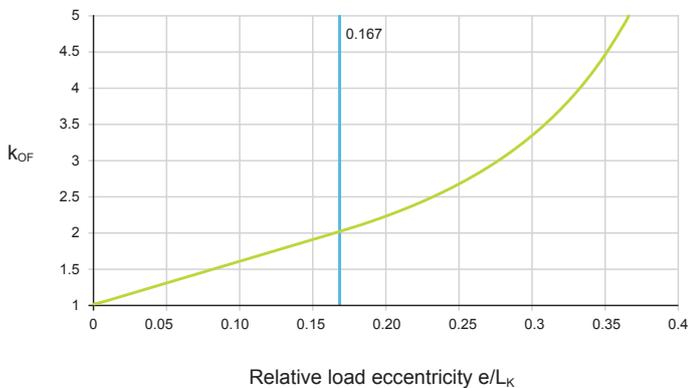
Figure 12. Static load factor for eccentrically loaded flat cages and open layout

△ If a load eccentricity of > 0.167 is exceeded, only part of the rolling element is loaded. This is extremely detrimental to the load carrying capacity and rigidity of the guidance system.

1.3.5.8 CALCULATION

Example

Input data

Guideways		M 5025 and V 5025
Flat cage assembly		E-HW15
Basic dynamic load rating for a cage length of 100 mm	C	$= 25960$ N
Basic static load rating for a cage length of 100 mm	C_0	$= 88900$ N
Operating load, functioning centrically on the guidance system (factors f_α, $f_{\alpha 0}$, $k_{0F} = 1$)	F	$= 9500$ N
Dynamic equivalent load	P	$= 9500$ N
Static equivalent load	P_0	$= 9500$ N
Distance from extreme stroke positions	H	$= 100$ mm
Number of double strokes per minute	n_{osz}	$= 50$ min^{-1}
Cage length	L_K	$= 300$ mm

Required data

Static load safety factor		S_0
Nominal rating life		L and L_h

Calculation

Verification of number of rolling elements per row (LA, L1, dimension tables)

$$Z = \left(\frac{L_K - 2L1}{LA} \right) + 1 \qquad Z = \left(\frac{300 - 7}{4.5} \right) + 1 = 66$$

For calculation:

$$L_K = (Z-1) \cdot LA + 2L1 = 299.5 \text{ mm}$$

Effective static load rating

$$C_{0w} = C_0 \cdot \frac{L_K - 2L1 + LA}{100}$$

$$C_{0w} = 88900 \cdot \frac{297}{100} = 264000 \text{ N}$$

Static load safety factor S_o

$$S_0 = \frac{C_{0w}}{P_0} \qquad S_0 = \frac{264000}{9500} = 27.8$$

Effective dynamic load rating C_w:

$$C_w = C \cdot \left(\frac{L_K - 2L1 + LA}{100} \right)^{3/4} \cdot \left(\frac{L_K - 2L1}{100 - LA} \right)^{1/36}$$

$$C_w = 25960 \cdot \left(\frac{295}{100} \right)^{3/4} \cdot \left(\frac{288}{95.5} \right)^{1/36} = 60250 \text{ N}$$

Nominal rating life L:

$$L = \left(\frac{C_w}{P} \right)^{10/3} \qquad L = \left(\frac{60250}{9500} \right)^{10/3} = 472 \cdot 10^5$$

Nominal rating life L_h

$$L_h = \frac{8.33 \cdot 10^5}{H \cdot n_{osz}} \cdot \left(\frac{C_w}{P} \right)^{10/3}$$

$$L_h = \frac{8.33 \cdot 10^5}{100 \cdot 50} \cdot 472 = 78600 \text{ h}$$

Calculation programme

The calculation on pages 21 to 27 can be used to establish an initial layout for flat cage guidance systems.
The equations are based on a defined static system.
In practice, however, an undefined static system is generally used. This does not allow for simple calculations; in order to obtain a precise calculation, the preload and internal load distribution have to be taken into account.
The load carrying capacity and rigidity for different loads can be calculated using a corresponding EGIS calculation programme.

The calculation programme determines the following data:
– Static load safety factor
– Displacement stemming from the elasticity of the bearing.

The non-linear deflection of the rolling elements is taken into account in this context.
The connecting structure is assumed to be rigid.

The following details are required for the calculation of every load scenario (figure 14 and datasheet, page 29):
– Size and position of the elements of the guidance system
– Position of the drive axis
– Position of the loading point and external load components
– Shear-free moments
– Position of the balance points and size of weights
– Kinetic valves
– Duration of particular steps

The geometry and loads can be described simply using the following datasheet.
A right-handed coordinate system is used for the description. The right-hand rule applies for moments.

Position of co-ordinate origin:
– Carriages in central stroke position
– x: centre of bearing cage length
– y: centre plane of guideways
– z: central between the guideways

One or more stroke positions deviating from the central position may be used for the calculation.

The data entered in the datasheet correspond to the guidance system presented in figure 15 as an example.
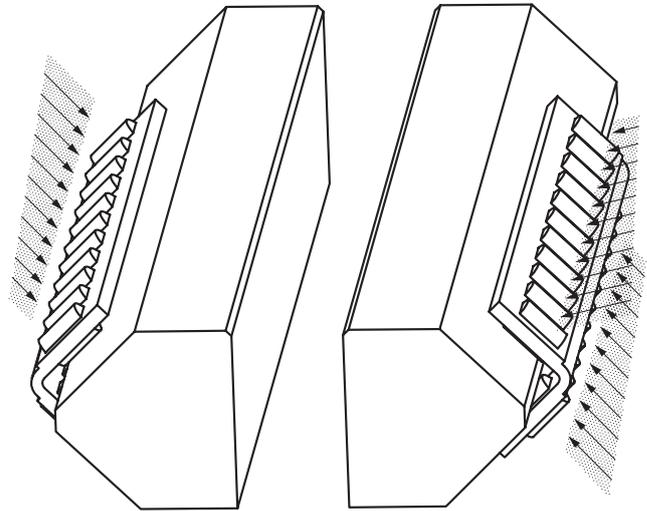
Figure 13. Internal load distribution in the case of loads produced by loads and moments
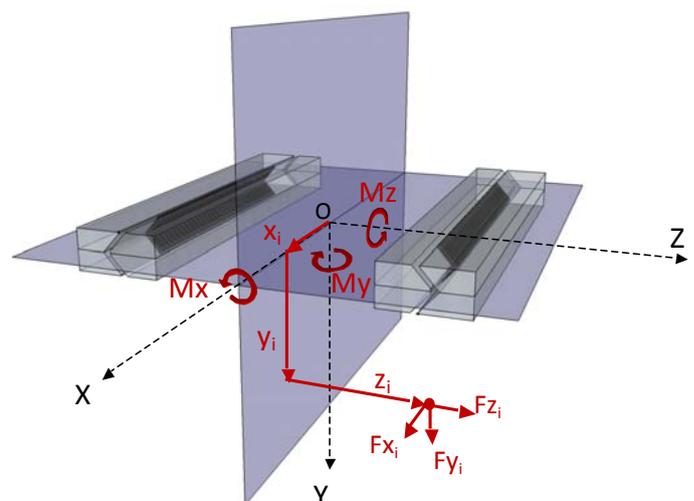
Figure 14. Coordinate system

Datasheet

Project :	Example
Guidance system :	Horizontal drilling carriage

Guidance geometry		
Guideway size	4020	
Cage length L_K	200	mm
Distance between rear guideway surfaces b1	145	mm
Installation layout	XI	
Stroke H	110	mm

Position of drive axis		
y_A	-32	mm
z_A	30	mm

Load case No./ description	Nr.	1	Drilling

Carriage position(s) for the calculation x_B	50			mm
Speed v	3			m/min
Duration of particular step q	50			%

Point i	Description	Coordinates			Loads, components			Moments		
		x_i	y_i	z_i	F_{xi}	F_{yi}	F_{zi}	M_{xi}	M_{yi}	M_{zi}
		mm	mm	mm	N	N	N	Nmm	Nmm	Nmm
1	Drilling tool: drilling pressure, torque	195	-90	0	-1200			-20000		
2	Carriage + shaft weight	55	-40	0		800				
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										

Example: horizontal drilling carriage

Installation layout

XI
X layout, internal carriage

XA
X layout, external carriage

OI
O layout, internal carriage

OA
O layout, external carriage

Figure 15. Geometry and load details

Example: horizontal drilling carriage

Results

Power on carriage drive	**Fx =**	-1200 N
Resulting load on guidance system:	**Fy =**	800 N
	Fz =	0 N
	Mx =	-20000 Nmm
	My =	-36000 Nmm
	Mz =	-82400 Nmm

Required preload power	**Pv =**	3050 N

Percentage rate of static load carrying capacity	**C_0:**	2.54 %

Displacement of the guidance system:	**del y =**	0.13992 µm
	del z =	-0.00719 µm
	phi x =	-0.00152 mrad
	phi y =	-0.00389 mrad
	phi z =	-0.00863 mrad

Static load safety factor:	**S_0**	= 31.6

Displacement at point i (µm)

Nr.	del ix	del iy	del iz
1	-0.27622	0.18561	0.04155
2	-0.77686	-1.54327	0.88915
3	-0.34527	-0.33483	0.26788

The calculated displacements only include the effect of the deflection of rolling elements and raceways.
The deformation of the connecting structure is not taken into account.

1.4 RIGIDITY

Flat cage guidance systems use needle rollers, cylindrical rollers or balls as load-bearing rolling elements. Needle rollers and cylindrical rollers possess a line contact in the rolling contact whilst balls possess a point contact. The operating load F creates an elastic deformation at the contact points and therefore causes the raceways to converge around the deflection δ.

Rigidity is the relationship between the load and deformation:

$$C_L = \frac{F}{\delta}$$

Guidance systems with needle rollers are significantly more rigid than those with cylindrical rollers given the same space requirement due to the large number of contact lines.
The rigidity of guidance systems with balls is considerably lower on account of the point contact (figure 16).
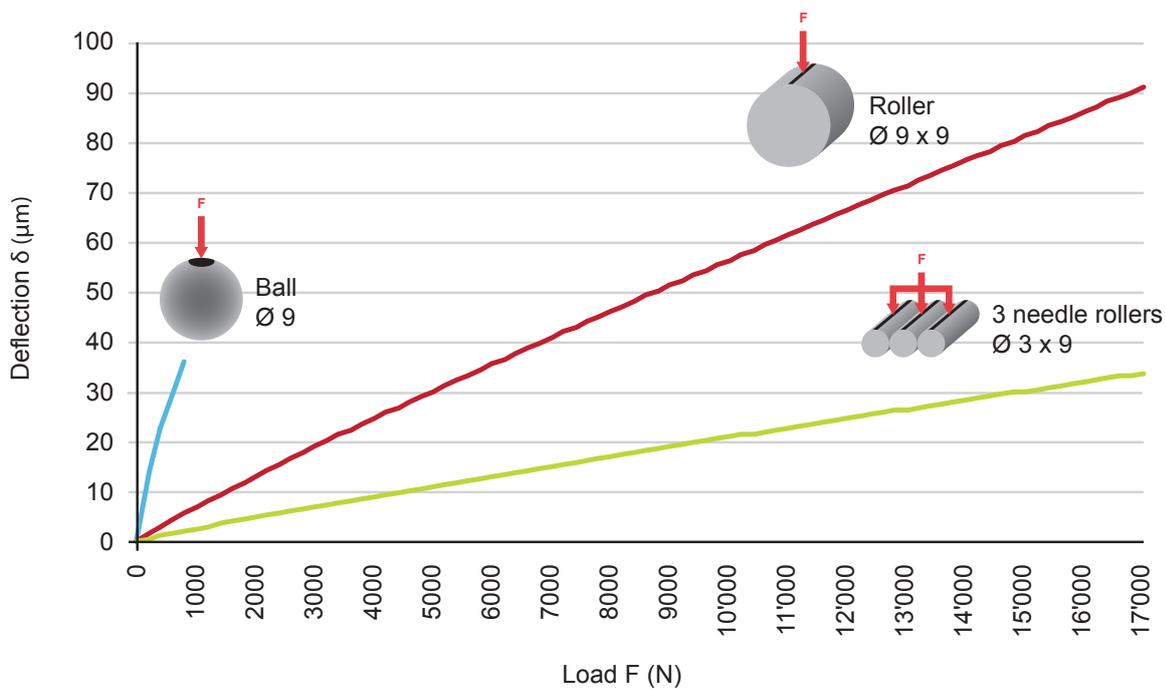
Figure 16. Comparison between rolling element types with the same space requirement

⚠ Deformations of the connecting structure, settlement phenomena, etc. are not taken into account. Deformation can therefore be more significant in practice.

In guidance systems with M and V guideways in a closed layout, the rigidity can be increased by preloading (preloading, page 34).

The rigidity is dependent on the load and
the number and geometry of the rolling elements.

Flat cage guidance systems with line contact

$$\delta = K \cdot (F/Z)^{0.9} / L_w^{0.8}$$

$$C_L = 1/K \cdot F^{0.1} \cdot Z^{0.9} \cdot L_w^{0.8}$$

Flat cage guidance systems with point contact

$$\delta = K \cdot (F/Z)^{2/3} / D_w^{1/3}$$

$$C_L = 1/K \cdot F^{1/3} \cdot Z^{2/3} \cdot D_w^{1/3}$$

δ	**µm**	Elastic deformation at the contact points, convergence of the two raceway levels
K	**-**	Factor for the determination of elastic deformation dependent of the type (table 17)
F	**N**	Operating load
Z	**-**	Number of rolling elements per row
L_w	**mm**	Rolling element length
C_L	**N/µm**	Rigidity of the flat cage guidance system
D_W	**mm**	Ball diameter.

Table 17: factor K for the determination
of elastic deformation

Calculation example

Guideway	M 5025 and V 5025
Flat cage assembly	E-HW15 x 300
Operating load	F = 9500 N
Number of rolling elements per row	Z = 66
Rolling element length	L_w = 6.8 mm
Type factor (table)	K = 0.0822

Elastic deformation calculation:

$$\delta = K \cdot (F/Z)^{0.9} / L_w^{0.8}$$

$$\delta = 0.0822 \cdot (9500/66)^{0.9} / 6.8^{0.8} = 1.6 \text{ µm}$$

Rigidity calculation:

$$C_L = 1/K \cdot F^{0.1} \cdot Z^{0.9} \cdot L_w^{0.8}$$

$$C_L = 1/0.0822 \cdot 9500^{0.1} \cdot 66^{0.9} \cdot 6.8^{0.8} = 6100 \text{ N/µm}$$

Guideway Type	Factor K	Guideway Type	Factor K
	0.0822		0.0426
	0.0794		0.8776
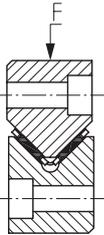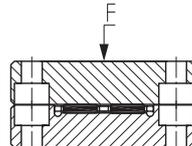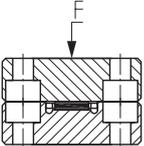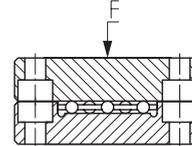
1.5 PRELOAD

The preload of flat cage guidance systems can be useful for the following reasons:

– Increase of rigidity
– Improvement of running accuracy
– Improvement of load distribution and reduction of maximum load on the outer rolling elements
– Increase of permissible moments

The preload influences the displacement resistance and rating life.

Reference value for the preload: 2 to 3% of C_0.
The optimum preload for concrete load datas can be determined using EGIS calculation programmes.

An optimum preload reduces the possibility of uncontrolled movement in the flat cage assembly (cage roaming).

In order to guarantee that the rigidity of our linear guidance systems is fully optimised, care must be taken to ensure that the connecting structure is sufficiently rigid and precise.

In the case of imprecise connecting structures or ones which can be easily deformed, angle errors may occur between the raceways which create an increased load at the ends of the rolling elements.

This would not result in increased rigidity but rather the end load would reduce the operating life.

1.5.1 SETTING THE PRELOAD

The preload can be measured and set using different methods:

– using pressure screws with a setting torque according to the table on page 35
– by means of FRV carriage displacement resistance (see below)
– by measuring the deformation of the connecting structure.

$$F_{RV} = \frac{C_{0w}}{40'000}$$

F_{RV}	**N**	Carriage displacement resistance
C_{0w}	**N**	Effective static load rating

Requirements:

– Preload 2,5% C_0
– Lubricated guidance system without operating load
– Movement at approx. 0,05 m/s

1.5.1.1 PRESSURE SCREWS

In the case of small loads ($S_0>5$) the guidance system can be preloaded by means of pressure screws.
A smaller effective span can be obtained by inserting the pressure screws (stud screws according to ISO 4026, DIN 913) between the attachment screws and at the end of the guideway (table 18, figure 19).

1.5.1.2 GUIDEWAYS WITH ADJUSTING GIB

The use of ML guideways with an adjusting gib is recommended where a high degree of rigidity is required or with larger loads ($S_0<5$). This ensures that the preload is distributed evenly over the entire guideway length.

TABLE 18. PRESSURE SCREWS / SETTING TORQUE

Guideways	Flat cage assembly	Pressure screw		Setting torque
		Dimension	Distance / mm	$M_E^{1)}$ / Nm
M / V 3015	E-HW10	M4	40	0.34
M / V 4020	E-HW15	M6	80	1.2
M / V 5025	E-HW16	M6	80	1.8
M / V 4525	E-HRW50	M6	80	1
M / V 6035	E-HW20	M8	100	2.9
M / V 6535	E-HRW70	M8	100	3.5
M / V 7040	E-HW25	M10	100	5.7
M / V 8050	E-HW30	M12	100	7.7

1) Torque for a preload of 2,5% C_0
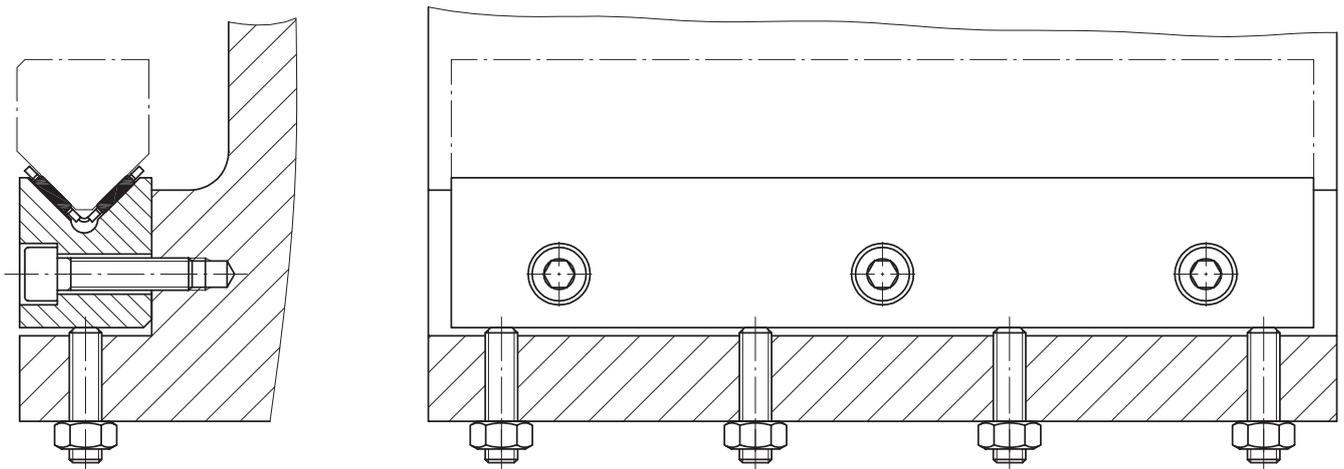
Figure 19. Position of the pressure screws

1.6 LUBRICATION

Machine performance is influenced considerably by the installed flat cage guidance systems. Lubrication plays an important role in this context.

The lubricant minimises friction and wear in the rolling contact and at the bearing points between the cage and the rolling elements. Lubricants also protect against corrosion and offer a support to the seal.

1.6.1 LUBRICANTS

Grease or oil can be used as lubricants.
The choice of lubrication procedure is made on the basis of technical and economic considerations:

Advantages of lubrication with grease:

– long relubrication intervals
– reduced structural expenditure when relubrication
  is not required
– thickener in the grease creates emergency
  operation features
– support to the seal

Advantages of lubrication with oil:

– excellent lubrication application
– dirt is flushed out
– heat is dissipated

Flat cage guidance systems only require minimal lubrication. They are supplied with a preservative. The preservative is compatible with grease and oils.

Flat cage guidance systems are generally operated in areas of mixed friction. For this reason, doped lubricants with high-pressure additives should be used (code letter P according to DIN 51502).

△ Cooling lubricants must not be used as they thin out
   the lubricants and can cause corrosion. Lubricants
   with solid additives must not be used.

1.6.2 LUBRICATING WITH GREASE

General recommendation:
Lithium-soap, EP-doped grease with mineral oil base.
Specification according to DIN 51825: KP2N-20
Base oil viscosity: ISO-VG 150 to ISP-VG220.

△ $S_0 < 8$ essential with large loads
   EP-doped greases with base oil viscosity
   of ISO-VG 220 should be used.

1.6.2.1 PRIMARY OPERATION AND GREASE QUANTITY

The guidance system must be protected against soiling before and during assembly.

Without relubrication equipment:
For the first lubrication application, spread the grease quantity according to the table over both sides in the cage pockets and thinly lubricate the guideway raceways.

With relubrication equipment:
First fill the feed line with grease and thinly lubricate the raceways. Then assemble the guidance system and feed in the grease according to the table. Move the guide system several times during this procedure over the entire stroke to ensure that the grease is evenly distributed.

TABLE 20. GREASE QUANTITIES FOR PRIMARY LUBRICATION (GUIDELINES)

Flat cage/Series	Grease quantity for primary lubrication g/100 mm cage length [1]
E-HW 10	0.6
E-HW 15[2] / E-FFW 2025 / E-FF 2025 ZW	0.6
E-HW 20[2] / E-FFW 2535 / E-FF 2535ZW	1
E-HW 25[2] / E-FFW 3045 / E-FF 3045 ZW	1.3
E-HW 30[2] / E-FFW 3555 / E-FF 3555 ZW	2.1
E-HRW 50	1.5
E-HRW 70	3.5
E-HRW 100	6.6
E-H 10[2] / E-FF 2010	0.3
E-H 15[2] / E-FF 2515	0.5
E-H 20[2] / E-FF 3020	0.7
E-H 25[2] / E-FF 3525	1.1

1) In case of high speeds only about 25% of the quantity
2) With flat cage assemblies with damping about 80% of the quantity

1.6.2.2 RELUBRICATION

Relubrication should be carried out at least once a year with approximately 50% of the grease quantity used for the primary lubrication. More frequent relubrication with partial quantities is recommended. The optimum time and quantities can only be determined under operating conditions and with an adequate observation period.

1.6.3 LUBRICATING WITH OIL

General recommendation:
CLP lubricating oils according to DIN 51517 and HLP according to DIN 51524

Operating temperatures from 0 °C to +70 °C:
Viscosity between ISO-VG 32 and ISO-VG 68

Low temperature range:
Viscosity ISO-VG 10 to ISO-VG 22

CGLP raceway oils can be used up to ISO-VG 220

Oil is fed in by oil impulse or drop feed. Pneumatic oil lubrication is recommended for working conditions with a significant risk of soiling. The slight excess pressure occurring in the guidance system enhances the effective-ness of the existing seals.

It is important to observe the layout (figure 21) when feeding in the lubricating oil so that the lubricant can reach all the rolling element rows.

If the oil manufacturer has not provided any details or experiences, the behaviour of the lubricating oil must be verified under operating conditions in comparison with the materials used in the guidance system.

Mineral oils can generally be mixed together.

However, synthetic oils must be verified in relation to miscibility and compatibility.

In case of doubt, contact the lubricant supplier.

Primary operation
Oil the guidance system and protect it against soiling during assembly.
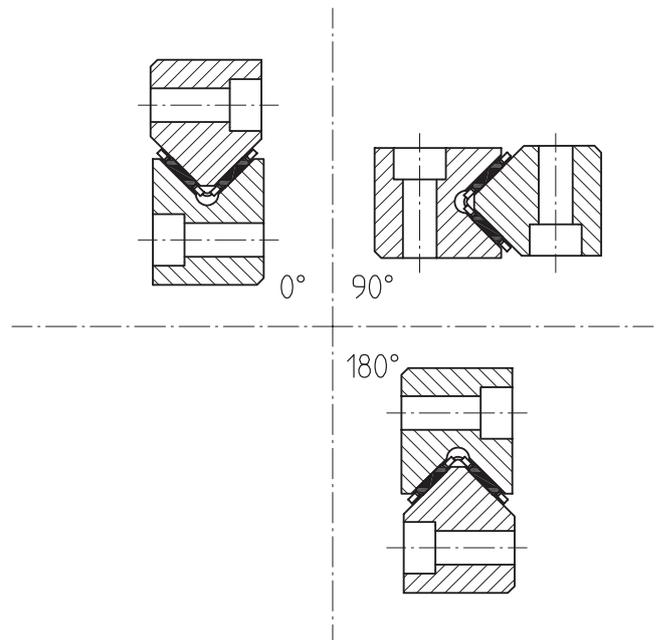
Figure 21. Layouts

1.7 FRICTION

As is the case of all roller bearings, flat cage guidance systems have virtually low friction during the start-up process and in motion. This means that no "stick-slip effect" is produced compared with sliding friction.

Friction (displacement resistance FR) is made up of the following components with different dependencies:

$$F_R = F_{R1} + F_{R0} + F_{RA}$$

Friction component		**Dependency**
Rolling friction	F_{R1}	Load/lubrication condition
Lubricant friction	F_{R0}	Cage dimensions
		Stroke speed
		Lubricant
Wiper friction	F_{RA}	Configuration, preload

Load-dependent rolling friction F_{R1}

$$F_{R1} = \mu \cdot F$$

F_{R1}	**N**	Load-dependent friction component
F	**N**	Flat cage load
μ	**-**	Friction coefficient

With lubrication, the friction coefficient amounts to
0.00035 for flat cage assemblies
0.00050 for angled flat cage assemblies

Lubricant friction F_{R0}

$$F_{R0} = f_0 \cdot (\nu \cdot v)^{2/3} \cdot B1 \cdot L_K{}^{1/3} \cdot 10^{-6}$$

F_{R0}	**N**	Lubricant friction component in displacement friction
f_0	**-**	Type factor
		$f_0 = $ 85 for flat cage assemblies
		$f_0 = $ 120 for angled flat cage assemblies
ν	**mm²s⁻¹**	Lubricant viscosity at operating temperature
		Viscosity of base oil with grease lubrication
v	**m/min**	Speed
B1	**mm**	Cage width
L_K	**mm**	Bearing cage length

Primary lubrication or relubrication produce temporarily raised lubrication friction.

Wiper friction F_{RA}

The wiper friction arise from the length of the wiper lip and the lip preload. This can be influenced considerably by the wiper assembly.

Reference value per wiper:

Profile shape M/V $F_{RA} = 0.20 \cdot B$

Profile shape J/S $F_{RA} = 0.15 \cdot B$

F_{RA}	**N**	Friction per wiper
B	**mm**	Guideway width

1.8 PROTECTION AGAINST SOILING

In order to ensure that flat cage guidance systems operate safely it is extremely important to protect them against soiling.

In many cases, wipers will suffice to keep the raceways clean. They must be positioned on the raceways throughout the entire movement.

Complete solutions for M and V guideways with standard wipers and integrated longitudinal seals
(suffix ..ZZ, ..PP) or seals in the connecting structure may be used for more demanding cases.

1.9 OPERATING LIMITS

Operating temperatures

Linear guidance systems with metallic flat cages are suitable for continuous temperatures of up to +150 °c.

Suitable lubricants must be used in this case.
The guideways must be heat-stabilised at higher operating temperatures (further information can be obtained from EGIS).

Linear guidance systems with flat cages made from plastic are suitable for temperatures of up to +120°C.

An operating temperature of +100 °C must not be exceeded when using wipers.

Acceleration

If high accelerations are recorded in a linear guidance systems, EGIS light metal flat cages are particularly recommended due to their reduced weight.
They can be used for accelerations up to 250 m/s^2.

1.10 INSTALLATION GUIDELINES

1.10.1 PRECISION OF THE CONNECTING STRUCTURE

The precision of the locating surfaces has a decisive influence on the accuracy and smooth running of a linear guidance system.

Perpendicularity and parallelism

The right angle between the locating surfaces must be maintained precisely
(permissible error ± 0,3 mrad)

⊥ 0.003/10

Parallelism errors on the locating surfaces must not be significantly greater than the corresponding tolerances of the guideways.

Figure 22. Height variation with a closed layout

Height variation

In order to ensure that the load is distributed as equally as possible over the length of the rolling element, the height variation Δh should not be exceeded (figures 22 and 23).

Permissible height variation for needle roller flat cage assemblies
$\Delta h < 0,1 \cdot b$
Permissible height variation for cylinder roller flat cage assemblies
$\Delta h < 0,3 \cdot b$

Δh	µm	Permissible height variation
b	**mm**	Distance between guidance system centres

Figure 23. Equalisation of the height variation with an open layout with an insert plate

Surface

No particular demands are placed on the surface roughness of the locating surfaces from an operational point of view. In order to maintain a high level of form precision and a suitable measurement basis, it is nevertheless recommended that the surfaces should be precision machined and the holes carefully deburred.

1.10.2 ASSEMBLY INSTRUCTIONS

1.10.2.1 PRIOR TO INSTALLATION

Guideways are preserved and delivered packed in anticorrosion paper. Parts are matched by dimensions, packed in sets and numbered accordingly.

Numbering: **1 . 2**

| set number | Joint number |

Unpack guideways shortly before assembly and remove the corrosion protection where applicable. Light oiling protects the guideways against corrosion during assembly. Position parts with identical set number.

Particular attention should be paid to the following points:

– Guideways with the same set number should be inserted in the same guidance system during assembly.
– Attention should be paid to the joint number at the joints.
– The M and V guideways may have different set numbers in the closed layout (figure 24).
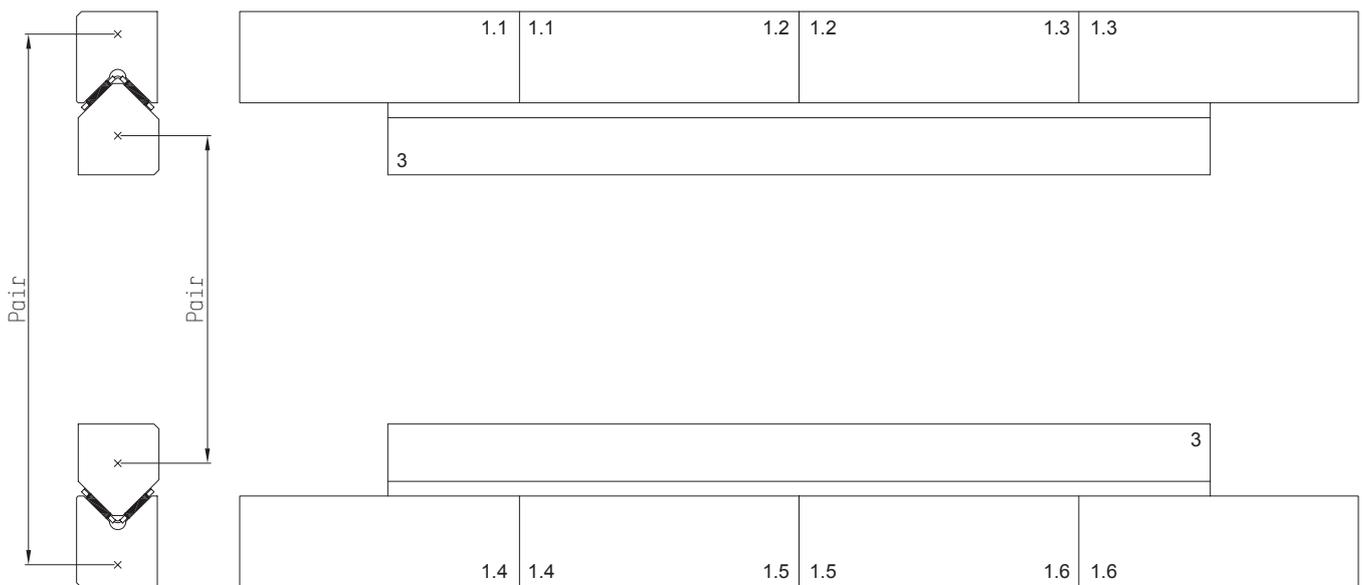
Figure 24. Numbering of single and multi-part guideways

1.10.2.2 CLOSED LAYOUT

⚠ Guideways which are packed in pairs must always be installed in the same guidance system.

The guideway locating faces are unlabelled and comprise significant chamfer.

Assemble the guideway pair which does not require adjustment (1) (figure 25). Clamp the guideways against the rear locating face and check for parallelism before tightening the fixing screws (figure 26).

Assemble the stationary opposing guideway (2)

Attach the adjusting guideway (3), only tightening screws slightly so that the guideway can still move.

Insert guidance system lengthways, insert cage assemblies between the guideways and position so that they do not lie against the end pieces in the final positions.

Preload adjusting guideway (3) with pressure screws (4) (figure 27) (with gib for ML guideways) (figures 29 to 31).

Initially preload around twice the required value in order to anticipate settling. Release and then set the preload to the required value. Tighten fixing screws. Screw on wipers or end pieces.

When preloading with pressure screws, adjust the latter in two steps to the required tightening torque and tighten with a counter nut or screw locking device.
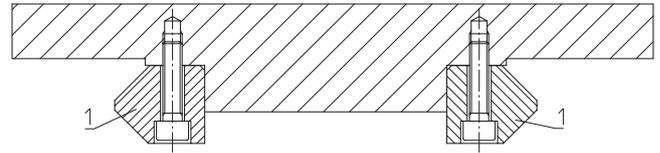
Figure 25. Assembly.
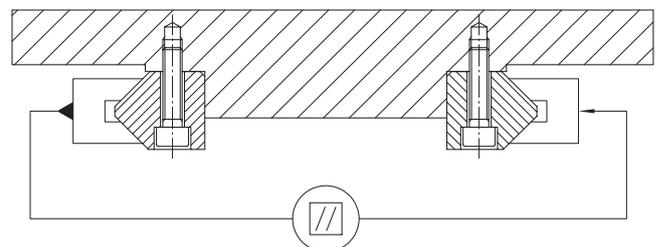
Figure 26. Parallelism verification
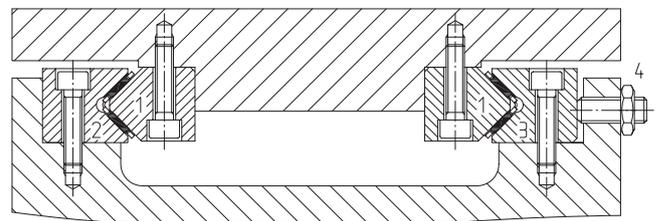
Figure 27. Preload.

⚠ Only tighten pressure screws which are supported by the flat cage assembly (see figure 28).
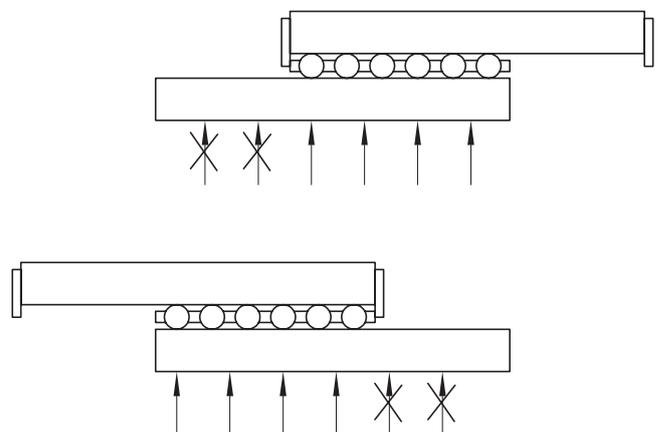
Figure 28. Preload adjustment.

If the preload force is adjusted over ML- guideways with an adjusting gib, the following procedure should be followed: push the adjusting gib under the ML guideway and adjust the guidance system free from clearance (figure 29). Shorten the unhardened gib on the adjustment side of the guideway so that it is approximately 3 mm short of the front side of the guideway (figure 29). Shorten the opposite side of the gib flush with the end of the guideway.

Preload the gib by inserting a soft bolt (figure 30). A 1 mm displacement of the gib produces a height adjustment of 15 μm.

After setting, attach the adjusting gib to the front side of the guideway with the hexagonal socket screw (figure 31).

See chapter entitled "Setting the preload" to verify the preload

1.10.2.3 OPEN LAYOUT

After the precision of the locating faces has been checked, particularly the height variation (see chapter on the precision of the connecting parts), the guideways can be assembled in the required sequence.

Guideways which are labelled in sets (4SX matching) must be assembled accordingly.
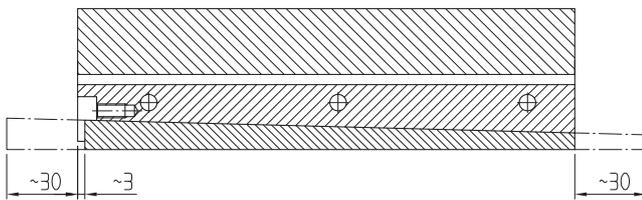
Figure 29. Inserting and shortening the adjusting gib
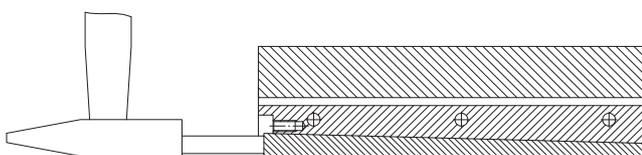
Figure 30. Setting the preload
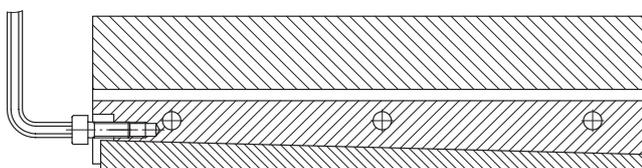
Figure 31. Attaching the adjusting gib