

**12 Load carrying capacity and service life****12.1 Basic principles**

The load capacities are based on DIN ISO standard 14728 for roller-contact bearings.

In accordance with DIN, in most applications a permanent overall deformation of 0.0001 times the rolling element diameter can be permitted without adversely affecting the operating behavior of the bearing. This is referred to as the static capacity,  $C_0$ . When designing a new application, we recommend the equivalent static load be in line with the dynamic load capacity (  $C$  ) to avoid plastic deformation.

The dynamic loading capacity  $C$  is the load at which a nominal service life  $L$  of 100,000 meters of travel is achieved. It is important to note when calculating the service life that not only the load, which acts vertically on the guideway, should be taken into account but the load range of all acting forces and moments.

The service life corresponds to the travel distance in meters, which is travelled from a guideway. This is before the first sign of material fatigue occurs within the roller guideway elements. The nominal service life is achieved when 90 % of the guideways of identical construction reach or exceed the corresponding travel distances under normal operating conditions.

Critical for the dimensioning of the guideways are the loads occurring in the ratio with the dynamic loading capacity  $C$ .

**Definition of service life**

As previously mentioned, the dynamic loading capacity  $C_{100}$  is based on a service life of 100,000 meters. Other manufacturers frequently indicate the loading capacity  $C_{50}$  for a service life of 50,000 meters. The resulting load capacities from this are more than 20 % higher than specified in the DIN ISO standard.

**Conversion examples****For balls**

Convert load capacities in accordance with DIN ISO standard to  $C_{50}$ :

$$C_{50} = 1.26 \cdot C_{100}$$

Convert  $C_{50}$  load capacities in accordance with DIN ISO standard to:

$$C_{100} = 0.79 \cdot C_{50}$$

**For rollers and needles**

Convert load capacities in accordance with DIN ISO standard to  $C_{50}$ :

$$C_{50} = 1.23 \cdot C_{100}$$

Convert  $C_{50}$  load capacities in accordance with DIN ISO standard to:

$$C_{100} = 0.81 \cdot C_{50}$$

$C_{50}$  = dynamic loading capacity  $C$  in N for 50,000 meters of travel distance  
 $C_{100}$  = dynamic loading capacity  $C$  in N for 100,000 meters of travel distance  
 defined in accordance with DIN ISO standard

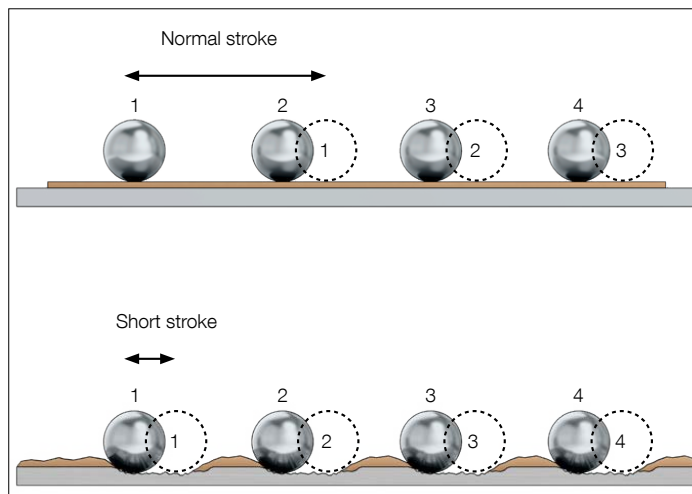
## 12 Load carrying capacity and service life

### 12.2 Short strokes

We talk about short stroke applications when a rolling element does not travel past the position of the next rolling element during a stroke.

A continuous lubricating film forms below the rolling element

Local depressions from wear and tear form on the tracks.  
At highly frequent strokes the lubricating film is also interrupted



Because the tracks are concentrated at these points (depressions from wear and tear form), the precision and service life of the guideway is reduced. When the strokes are highly frequent, a standard lubricant is no longer able to reach the points of contact.

Wear and tear can be deferred with **suitable lubricants** and regular **lubrication strokes**.

Short strokes curtail the service life of the guideway considerably. The service life of the guideway(s) can only be determined by means of testing.

**12 Load carrying capacity and service life****12.3 Calculating the service life L in accordance with the DIN ISO standard**

The formulas for calculating service life are:

**For rollers and needles:**

$$L = a \cdot \left( \frac{C_{eff}}{P} \right)^{\frac{10}{3}} \cdot 10^5 \text{ m}$$

**For balls:**

$$L = a \cdot \left( \frac{C_{eff}}{P} \right)^3 \cdot 10^5 \text{ m}$$

a = Event probability factor  
 $C_{eff}$  = Effective load carrying capacity per rolling element in N  
 P = Dynamic, equivalent load in N  
 L = Nominal service life in m

**Event probability factor a**

The load carrying capacities for roller-contact bearings correspond to the DIN ISO standard. This represents a value from the service life calculation, which is exceeded with a probability of 90 % during operational use of the guideway.

If the previously mentioned theoretical service life probability factor of 90% is not adequate, the service life values will need to be adjusted by a factor a.

Event probability in %	90	95	96	97	98	99
Factor a	1	0.62	0.53	0.44	0.33	0.21

**Effective load carrying capacity  $C_{eff}$** 

External influences such as track hardness and temperature can reduce the loading capacity C which means that  $C_{eff}$  needs to be calculated.

$$C_{eff} = f_{H1} \cdot f_T \cdot C$$

$C_{eff}$  = Effective load carrying capacity per rolling element in N  
 $f_{H1}$  = Hardness factor  
 $f_T$  = Temperature factor  
 C = Max. permissible load carrying capacity per rolling element in N

**12 Load carrying capacity and service life****Hardness factor  $f_H$** 

Materials in a frictionless guideway, which deviate from the standard conditions (HRC 58 - 62), can be recorded with the factor  $f_H$ :

Track hardness in HRC	20	30	40	50	55	56	57	58-62
Hardness factor $f_H$	0.1	0.2	0.3	0.6	0.8	0.88	0.95	1

**Temperature factor  $f_T$** 

Increased temperatures influence the operating conditions (material properties) and must be taken into account using the factor  $f_T$ .

Temperature of the guideway in °C	150	200	250	300
Temperature factor $f_T$	1	0.9	0.75	0.6

**Example calculation for  $C_{eff}$** 

Guideway type R6 => Hardness 58 - 62 HRC =>  $f_H = 1$   
 Temperature 200°C =>  $f_T = 0.9$   
 Cage AA 6 =>  $C = 530$  N per roller

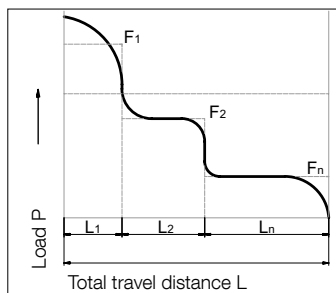
$$C_{eff} = f_H \cdot f_T \cdot C = 1 \cdot 0.9 \cdot 530 = \underline{477 \text{ N}}$$

## 12 Load carrying capacity and service life

### Dynamically equivalent load P

The loads (F) acting on a linear guideway system are subject to frequent fluctuations during operation. This set of circumstances should be taken into account when calculating service life. The varying load absorption of the guideway at varying operating conditions during the travel distance is described as being the dynamic equivalent load P.

#### Stepped load



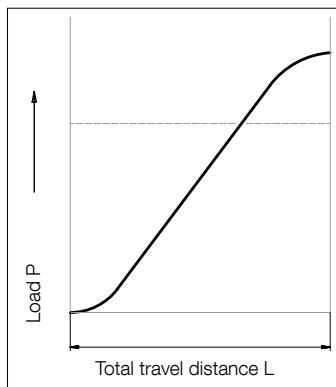
Formula for rollers and needles:

$$P = \sqrt[10]{\frac{1}{L} (F_1^{10} \cdot L_1 + F_2^{10} \cdot L_2 + \dots + F_n^{10} \cdot L_n)}$$

Formula for balls:

$$P = \sqrt[3]{\frac{1}{L} (F_1^3 \cdot L_1 + F_2^3 \cdot L_2 + \dots + F_n^3 \cdot L_n)}$$

#### Sinusoidal load



$$P = 0.7 F_{max}$$

P = Equivalent load in N  
F<sub>1</sub>...F<sub>n</sub> = Individual load in N during the partial travel distance L ... L<sub>n</sub>  
F<sub>max</sub> = Max. load in N  
L = L<sub>1</sub> + ... + L<sub>n</sub> = total travel during one load cycle in mm  
L<sub>1</sub>... L<sub>n</sub> = partial travel distance in mm of one individual load during a load cycle

Example calculation with a linear guideway of type RNG 6-300 with KBN 6 cage

- an event probability of 97% is selected; the corresponds to a factor a of 0.44
- the dynamic loading capacity of a roller (for KBN 6 cage) is 1'800 N. If 16 rollers are used, the loading capacity of the guideway is 16 · 1'800 N = (28'800 N)
- the application generates a total load on to the guideway of 10'000 N

With the previously mentioned values, the following calculation for service life L is:

$$L = a \cdot \left( \frac{C_{eff}}{P} \right)^{\frac{10}{3}} \cdot 10^5$$

$$L = 0.44 \cdot \left( \frac{28'800 \text{ N}}{10'000 \text{ N}} \right)^{\frac{10}{3}} \cdot 10^5 = 1'495'412 \text{ m}$$

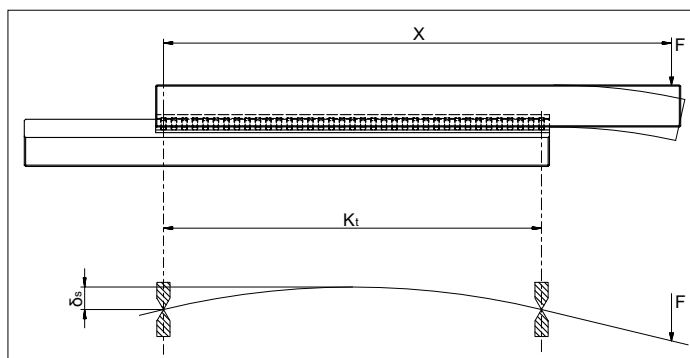
If the service life is requested in hours, the travelled stroke H (in meters) and the time t (in seconds) required for the stroke movement must be known.

The service life L<sub>h</sub> is calculated as follows:

$$L_h = \frac{L \cdot t}{H \cdot 3'600} = \text{Service life in hours}$$

## 12 Load carrying capacity and service life

The correction factor  $R_{Tmin}$



It was explained on the above pages how service life should be calculated from the given load carrying capacity and the occurring load. In doing so, the number of load bearing rolling elements per cage ( $R_z$ ) should be taken into account.

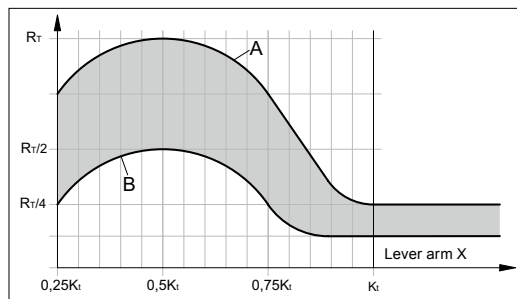
Similarly important is estimating the behavior of the surrounding structure when transmitting forces to the frictionless guideway. Then an elastic deformation or a geometric error in a machine bed lead to the fact that only a part of the installed rolling element effectively absorbs load.

Reliable statements on this application-specific issue can usually only be made with a great deal of difficulty, for example by taking measurements on functioning models or using calculations based on the method of finite elements. The result of this is that normally dimensioning takes place by taking simplified measures, i.e. the external load is divided up on to few rolling elements using the correction factor  $R_{Tmin}$ .

To determine  $R_{Tmin}$  first of all the connecting structure must be assessed based on the following values from historical experience:

- A = Rigid structure  
 $\delta_S \leq 0.1 \cdot \delta_A$
- B = Normal structure  
 $\delta_S > \delta_A$

$\delta_S$  = deformation of the connecting structure in  $\mu m$   
 $\delta_A$  = deformation of the rolling element including the guide rail in  $\mu m$   
 (see chapter 12.5)  
 $F$  = load in N  
 $X$  = distance in mm  
 $K_t$  = load-bearing cage length in mm

**12 Load carrying capacity and service life**

To calculate  $R_{Tmin}$  according to the diagram applies

structure	A (rigid)	B (normal)
$X > K_t$	$R_{Tmin}$ to $R_T/4$	$R_{Tmin}$
$X < K_t$	as per diagram	as per diagram

For $R_{Tmin}$ the following applies	Rolling element type	Cage types
2	Balls	AK
1	Rollers	AA, AC, EE, KBN and KBS
5	Needles	SHW and HW
0.5	Recirculating unit with rollers	SR and NRT
1	Recirculating unit with balls	SK, SKD and SKC

**Example calculation No. 1**

AK 6 cage

X measures 200 mm

$K_t$  measures 90 mm

Consequently the method of calculation applies in accordance with " $X > K_t$ "

**Calculation for a rigid structure:**

- In accordance with the table, a ball count applies of  $R_{Tmin}$  to  $R_T/4$
- $R_{Tmin}$  corresponds to 2 balls
- $R_T/4$  corresponds to 2.25 balls

**Calculation for a normal structure:**

- In accordance with the table  $R_{Tmin}$  corresponds to 2 balls

**Example calculation No. 2**

AK 6 cage

X measures 80 mm

$K_t$  measures 90 mm

Consequently the method of calculation applies in accordance with " $X < K_t$ "

**Calculation for a rigid structure:**

- In accordance with the diagram, X 0.88 from  $K_t$  is corresponding (80 mm : 90 mm) and consequently  $R_T/2$   
For 9 load bearing balls, this results in 4.5 balls (9 load bearing balls : 2)

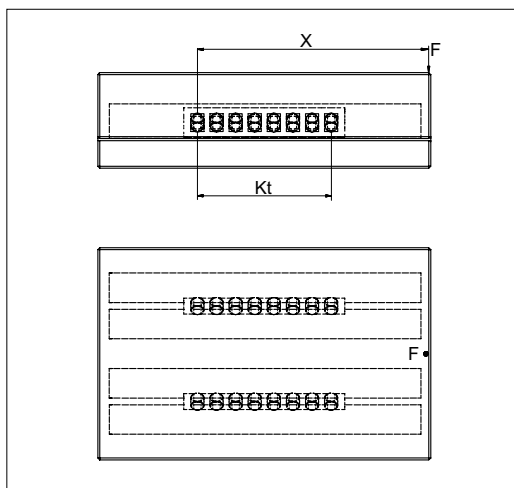
**Calculation for a normal structure:**

The following applies in accordance with diagram  $R_{Tmin}$ , which corresponds to 2 balls in accordance with the table

## 12 Load carrying capacity and service life

### 12.4 Example calculations

The following example calculations illustrate the procedure for some typical problems.



#### Example 1

##### Searched for:

Equivalent load P per roller

##### Assumption:

Linear guides type R 6

AC 6 cage with 8 rollers (=  $R_A$ )

$F = 350 \text{ N}$

$X = 120 \text{ mm}$

For the roller cage type AC 6 the following applies:

$K_t = (R_A - 1) \cdot t = (8 - 1) \cdot 9 = 63$

$R_{Tmin} = 1 \text{ roller}$

$C = 530 \text{ N}$

(see technical data for the AC 6 cage)

##### Note:

The asymmetric distribution of force is most safely taken into account when the load on the number of load bearing rolling elements ( $R_{Tmin}$ ) for the guideway is reduced.

##### Calculation for P per roller

$$P = \frac{F \cdot x}{K_t \cdot 2} \cdot \frac{1}{R_{Tmin}}$$

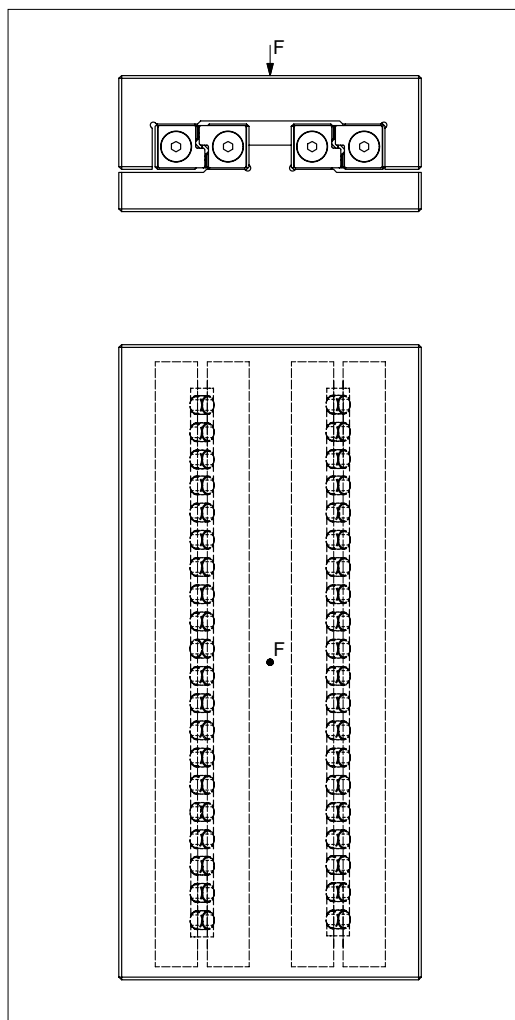
$$= \frac{350 \cdot 120}{63 \cdot 2} \cdot \frac{1}{1} = 334 \text{ N}$$

P is smaller than C. The design is correct in this way.

P	= Equivalent load in N per roller
F	= load in N
C	= Max. permissible load carrying capacity per rolling element in N
X	= distance in mm
$R_{Tmin}$	= Correction factor
$R_A$	= Total available rolling element per cage
t	= cage division in mm
$K_t$	= Load-bearing length in mm



## 12 Load carrying capacity and service life



### Example 2

#### Searched for:

Equivalent load P per roller

#### Assumption:

Linear guides type R 6

Roller cage type AC 6 cage with 20 rollers (=  $R_A$ )

$F = 6500 \text{ N}$

$C = 530 \text{ N}$  (according to techn. data for the AC 6 cage)

$$R_T = \frac{R_A}{2}$$

$$= \frac{20}{2} = 10 \text{ rollers}$$

#### Calculation for P per roller

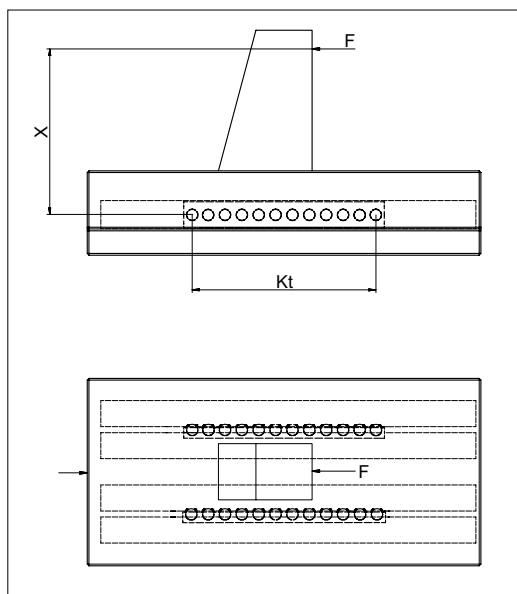
$$P = \frac{F}{2} \cdot \frac{1}{R_T}$$

$$= \frac{6500}{2} \cdot \frac{1}{10} = 325 \text{ N}$$

P is smaller than C. The design is correct in this way.

w = Distance from cage start to the middle of the first rolling element in mm  
t = cage division in mm  
P = Equivalent load in N per roller  
F = load in N  
C = Max. permissible load carrying capacity per rolling element in N  
 $R_T$  = Number of load-bearing rolling elements per cage

## 12 Load carrying capacity and service life



### Example 3

#### Searched for:

Equivalent load P per ball

#### Assumption:

Rigid slide structure

Linear guides type R 6

Cage type AK 6 with 12 balls ( $= R_A$ );  $t = 9 \text{ mm}$   
(according to techn. data for the AK 6 cage)

$$R_A = R_T = 12 \text{ balls}$$

$$R_{Tmin} = 3 = R_T/4 \text{ according to diagram on page 101}$$

$$K_t = (R_A - 1) \cdot t$$

$$F = 240 \text{ N}$$

$$X = 75 \text{ mm (distance F to opposing force)}$$

$$C = 65 \text{ N (according to chapter 5.1, technical data for the AK 6 cage)}$$

#### Calculation for P per ball:

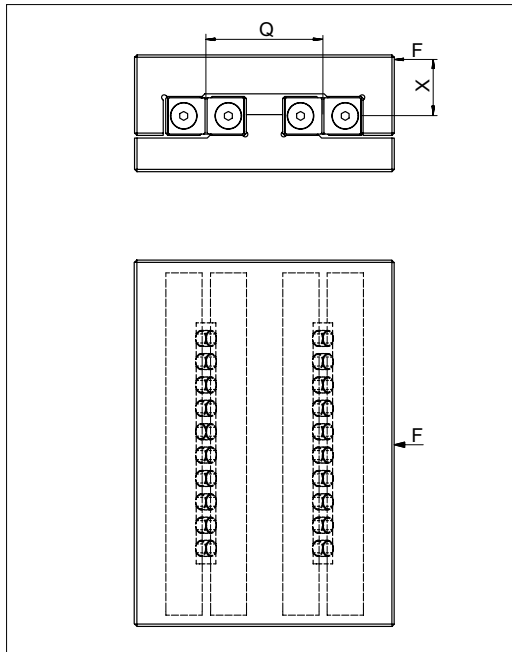
$$P = \frac{F}{K_t} \cdot \frac{X}{2} \cdot \frac{1}{R_{Tmin}}$$

$$= \frac{240}{99} \cdot \frac{75}{2} \cdot \frac{1}{3} = 30 \text{ N}$$

P is smaller than C. The design is correct in this way.

t	= cage division in mm
P	= Equivalent load in N per ball
F	= load in N
C	= Max. permissible load carrying capacity per rolling element in N
$R_{Tmin}$	= Correction factor
$R_A$	= Total available rolling element per cage
$R_T$	= Number of load-bearing rolling elements per cage
$K_t$	= Load-bearing length in mm

## 12 Load carrying capacity and service life



### Example 4

#### Searched for:

Equivalent load P per roller and the suitable size  
RNG guideways

#### Assumption:

Type RNG linear guideways

Roller cage type KBN with 10 rollers ( $R_A$ )

$F = 15'000 \text{ N}$

$X = 50 \text{ mm}$

$Q = 100 \text{ mm}$

$$R_T = \frac{R_A}{2}$$

$$= \frac{10}{2} = 5 \text{ rollers}$$

#### Calculation for P per roller

$$P_1 = \frac{F \cdot X}{Q} \cdot \frac{1}{R_T}$$

$$= \frac{15'000 \cdot 50}{100} \cdot \frac{1}{5} = 1'500 \text{ N}$$

$$P_2 = \frac{F}{R_A}$$

$$= \frac{15'000}{10} = 1'500 \text{ N}$$

$$P = P_1 + P_2$$

$$= 1'500 + 1'500 = 3'000 \text{ N}$$

P ( $P_1$ ,  $P_2$ ) = Equivalent loads in N per roller  
F = load in N  
X = distance in mm  
Q = Medium linear guideway distance in mm  
C = Max. permissible load carrying capacity per rolling element in N  
 $R_T$  = Number of load-bearing rolling elements per cage  
 $R_A$  = Total available rolling element per cage

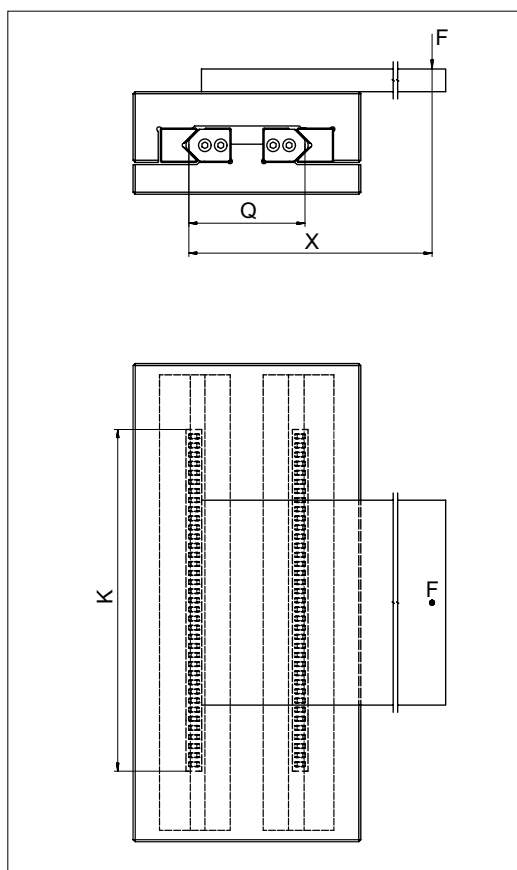
#### Definition of the suitable guideway size:

According to product specification for the KBN cage (chapter 5.2 or 5.3) if  $C = 3'900 \text{ N}$  were to be selected

Type	Size	Dw	t	w	C per roller in N
KBN	4	4.5	6.5	approx. 4	850
	6	6.5	8.5	approx. 5	1800
	9	9	12	approx. 7.5	3900
	12	12	15	approx. 9	6500

The roller size 9 is suitable. Thus select cage KBN 9 and the linear guideway RNG 9, provided the service life has been fulfilled.

## 12 Load carrying capacity and service life



### Example 5

#### Searched for:

Equivalent load P per needle

#### Assumption:

Linear guideways type N/O 2025

SHW 15 cage, cage length K = 194 mm

(w = 2.9 mm according to techn. specifications of the SHW 15 cage)

F = 5'000 N

X = 280 mm

Q = 75 mm

C = 750 N (according to techn. specifications for the AC 15 cage)

$$R_A = \left( \frac{K - 2w}{t} + 1 \right) \cdot 2$$

$$= \left( \frac{194 - 5.8}{4} + 1 \right) \cdot 2 = 96 \text{ needles}$$

$$R_T = \frac{R_A}{2} = 48 \text{ needles}$$

#### Calculation for P per needle:

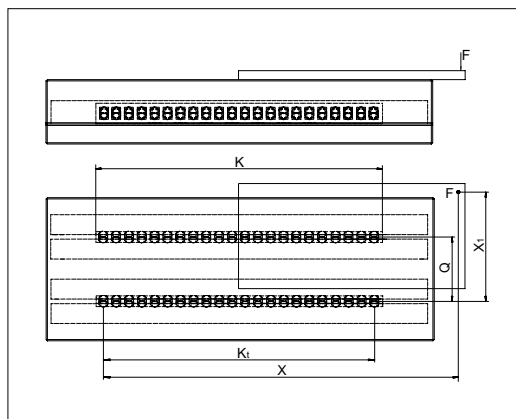
$$P = \frac{F \cdot X}{Q} \cdot \frac{1}{R_T}$$

$$= \frac{5'000 \cdot 280}{75} \cdot \frac{1}{48} = 389 \text{ N}$$

P is smaller than C. The design is correct in this way.

w	= Distance from cage start to the middle of the first rolling element in mm
t	= cage division in mm
P	= Equivalent load in N per needle
F	= load in N
X	= distance in mm
Q	= Medium linear guideway distance in mm
C	= Max. permissible load carrying capacity per rolling element in N
R <sub>T</sub>	= Number of load-bearing rolling elements per cage
R <sub>A</sub>	= Total available rolling element per cage
K	= Cage length in mm

## 12 Load carrying capacity and service life



### Example 6

#### Searched for:

Equivalent load P per roller

#### Assumption:

Rigid structure

Linear guides type R 12

Cage type AC 12, length K = 400 mm

F = 2'000 N

X = 500 mm

X1 = 200 mm

Q = 100 mm

C = 2'500 N (see chapter 5.1, technical specifications for the AC 12 cage)

For the roller cage AC 12 the following applies:

$$K_t = K - 2w = 400 - 22 = 378 \text{ mm}$$

$$R_A = \frac{K_t}{t} + 1 = \frac{378}{18} + 1 = 22 \text{ rollers}$$

$$R_T = \frac{R_A}{2} = \frac{22}{2} = 11 \text{ rollers}$$

$X > K_t = R_T/4$  (according to the diagram on page 101)

$$R_{TQ} = R_T$$

$$R_{TL} = \frac{R_T}{4} = \frac{11}{4} = 2.75 \text{ rollers (rounded down to 2)}$$

#### Calculation for P per roller

Load laterally

$$P_Q = \frac{F \cdot X_1}{Q} \cdot \frac{1}{R_{TQ}} = \frac{2'000 \cdot 200}{100} \cdot \frac{1}{11} = 364 \text{ N}$$

Load longitudinally

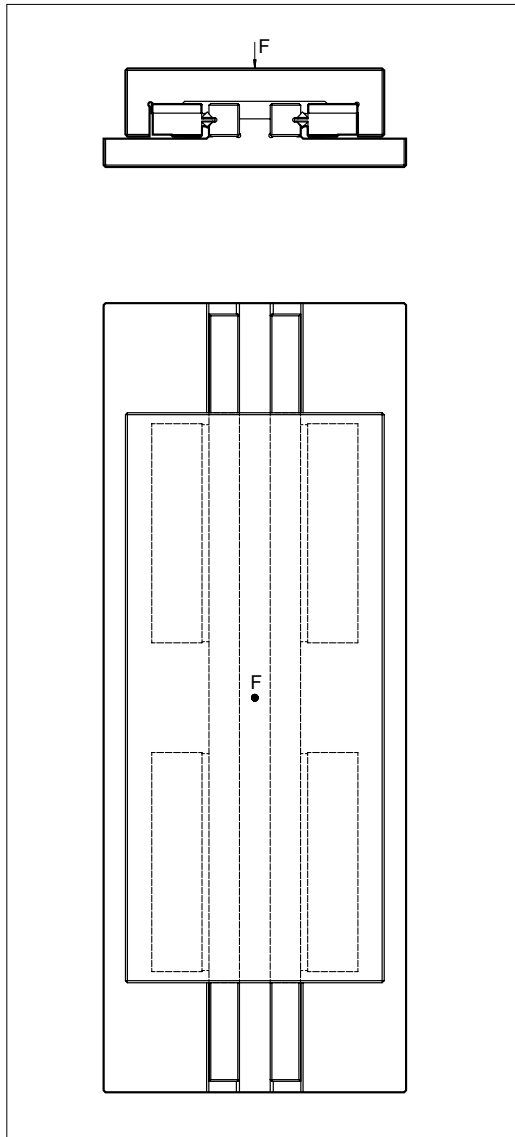
$$P_L = \frac{F \cdot X}{K_t \cdot 2} \cdot \frac{1}{R_{TL}} = \frac{2'000 \cdot 500}{378 \cdot 2} \cdot \frac{1}{2} = 662 \text{ N}$$

$$P = P_Q + P_L = 364 + 662 = 1'026 \text{ N}$$

P is smaller than C. The design is correct in this way.

w	= Distance from cage start to the middle of the first rolling element in mm
t	= cage division in mm
P	= Equivalent load in N per roller
F	= load in N
X	= distance in mm
X1	= distance in mm
Q	= Medium linear guideway distance in mm
C	= Max. permissible load carrying capacity per rolling element in N
RA	= Number of load-bearing rolling elements per cage
K	= Total available rolling element per cage
Kt	= Cage length in mm
...L	= Load-bearing length in mm
...Q	= Longitudinally
	= Laterally

## 12 Load carrying capacity and service life



### Example 7

**Searched for:**  
Equivalent load P

**Assumption:**

Recirculating unit type SR 6-100

Linear guides type R 6

$R_T = 2$  recirculating unit

$F = 6'000$  N

$C = 2'150$  N (see chapter 6.3, technical specifications for the recirculating unit)

**Calculation for P:**

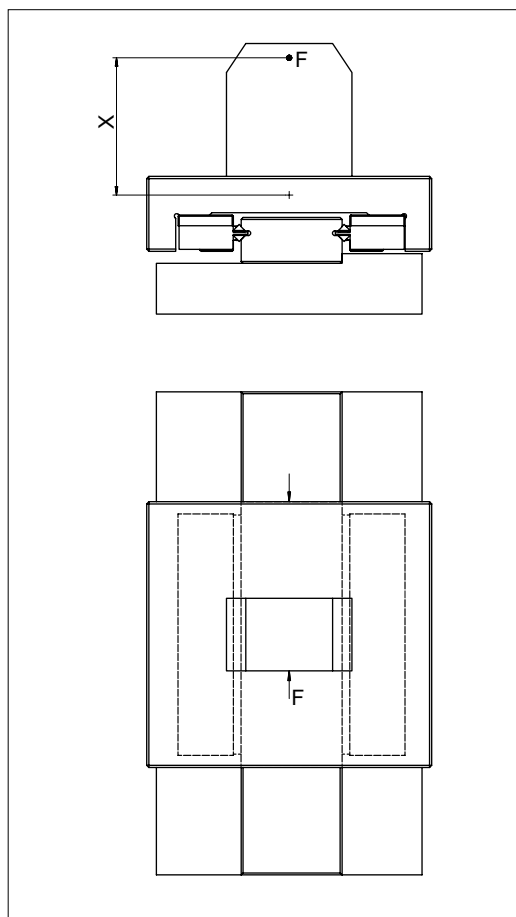
$$P = \frac{F}{2} \cdot \frac{1}{R_T}$$

$$= \frac{6'000}{2} \cdot \frac{1}{2} = 1'500 \text{ N}$$

P is smaller than C. The design is correct in this way.

P = Equivalent loads in N  
F = load in N  
C = Max. permissible load carrying capacity in N  
 $R_T$  = Number of load-bearing recirculating units

## 12 Load carrying capacity and service life



### Example 8

#### Searched for:

Moment load  $M$  in Nm longitudinally and laterally

#### Assumption:

Recirculating unit type SR 6-150

Linear guideways type RD 6

$M_L = 112$  Nm (according to chapter 6.3, technical specifications

for the recirculating unit)

$X = 45$  mm (distance  $F$  to opposing force)

$F = 2'000$  N

#### Calculation for $M$ :

$$M = F \cdot X = 2000 \cdot 0,045 = 90 \text{ Nm}$$

The moment load  $M$  is below the permissible load  $M_L$ . Thus the design is correct.

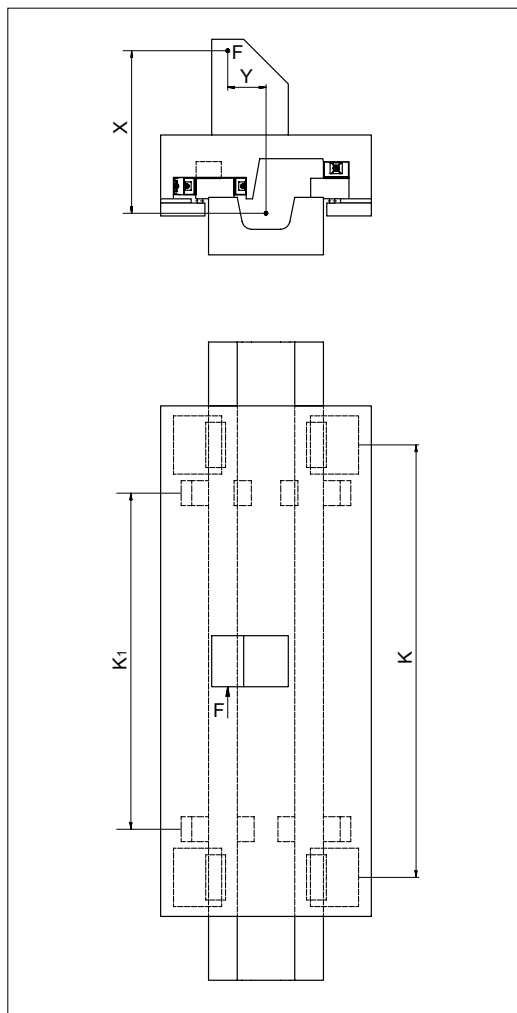
$M$  = Moment load in Nm longitudinally and laterally

$M_L$  = Permitted moment load in Nm longitudinally and laterally

$X$  = distance in mm

$F$  = load in N

## 12 Load carrying capacity and service life



### Example 9

#### Searched for:

Equivalent loads  $P_L$  and  $P_Q$

#### Assumption:

Recirculating unit top type NRT 26 111 ( $C = 98'000 \text{ N}$ )

Recirculating unit bottom type NRT 19 077 ( $C = 43'000 \text{ N}$ )

Recirculating unit side type NRT 19 077 ( $C = 43'000 \text{ N}$ )

$K = 700 \text{ mm}$

$K_1 = 450 \text{ mm}$

$R_{Tmin} = 0.5$  (according to table on page 101)

$F = 83'000 \text{ N}$

$X = 500 \text{ mm}$

$Y = 100 \text{ mm}$

#### Calculation for $P_L$ and $P_Q$ :

Load longitudinally

$$P_L = \frac{F \cdot X}{K \cdot 2} \cdot \frac{1}{R_{Tmin}}$$

$$= \frac{83'000 \cdot 500}{700 \cdot 2} \cdot \frac{1}{0.5} = 59'286 \text{ N}$$

Load laterally

$$P_Q = \frac{F \cdot Y}{K_1 \cdot 2} \cdot \frac{1}{R_{Tmin}}$$

$$= \frac{83'000 \cdot 100}{450 \cdot 2} \cdot \frac{1}{0.5} = 36'889 \text{ N}$$

$P$  = Equivalent load in N  
 $P_L$  = Equivalent load longitudinally in N  
 $P_Q$  = Equivalent load laterally in N  
 $F$  = load in N  
 $X$  = distance in mm  
 $Y$  = distance in mm  
 $C$  = Max. permissible load carrying capacity per recirculating unit in N  
 $R_{Tmin}$  = Correction factor  
 $K$  = distance in mm  
 $K_1$  = distance in mm



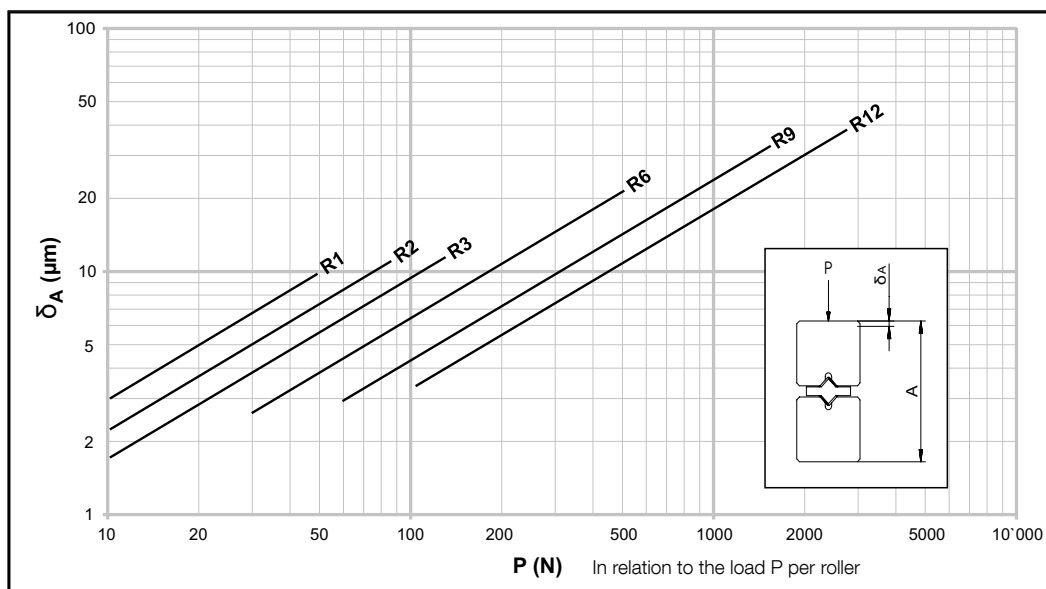
## 12 Load carrying capacity and service life

### 12.5 Elastic deformation and rigidity of linear bearings

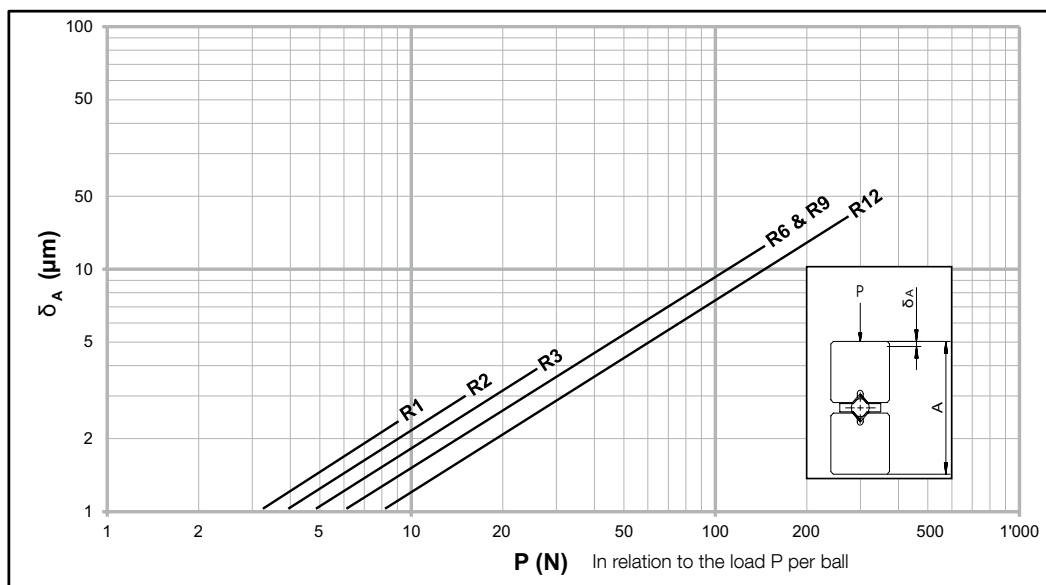
#### Linear guideways

The total deformation  $\delta_A$  (that is the deformation of the rolling element in connection with hardened tracks (min. 58 HRC) ) can be deduced from the following diagrams.

The elastic deformation of the linear guideways of type R with rollers

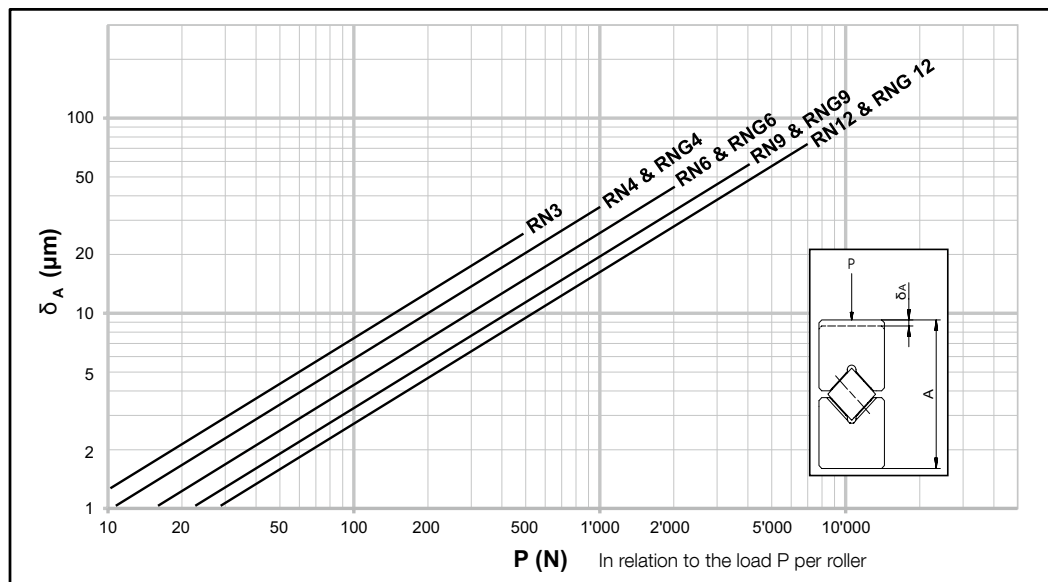


The elastic deformation of the linear guideways of type R with balls

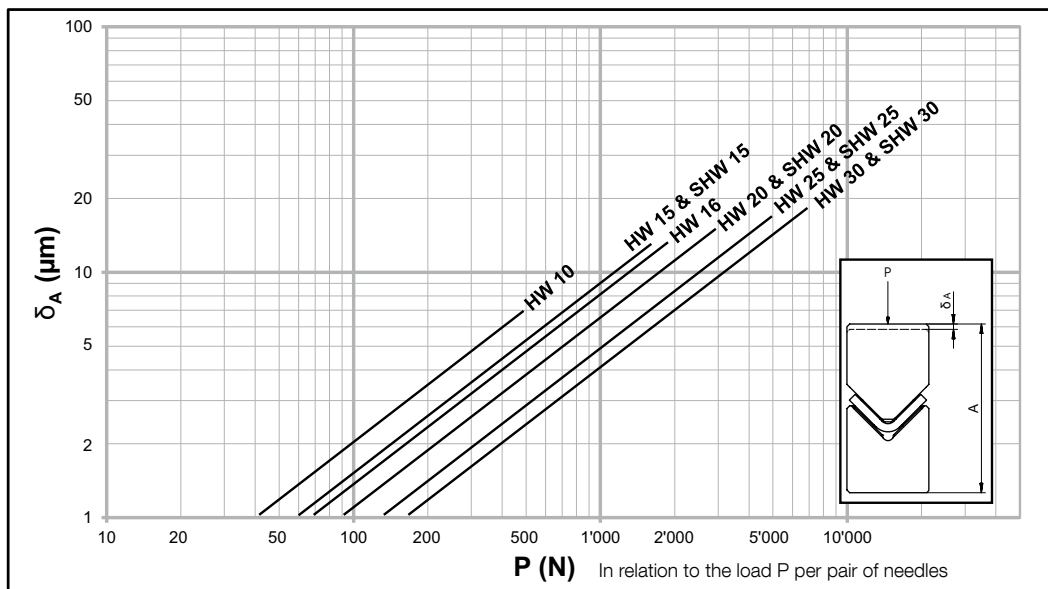


## 12 Load carrying capacity and service life

The elastic deformation of the linear guideways for type RN and RNG.



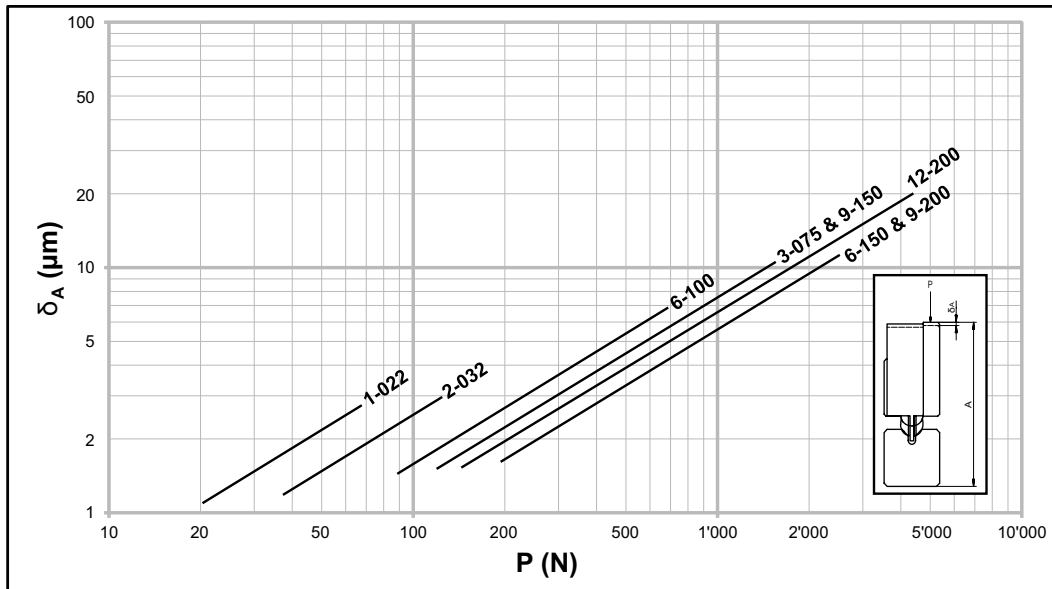
The elastic deformation of the linear guideways of types N/O and M/V upon use with the following types of cages



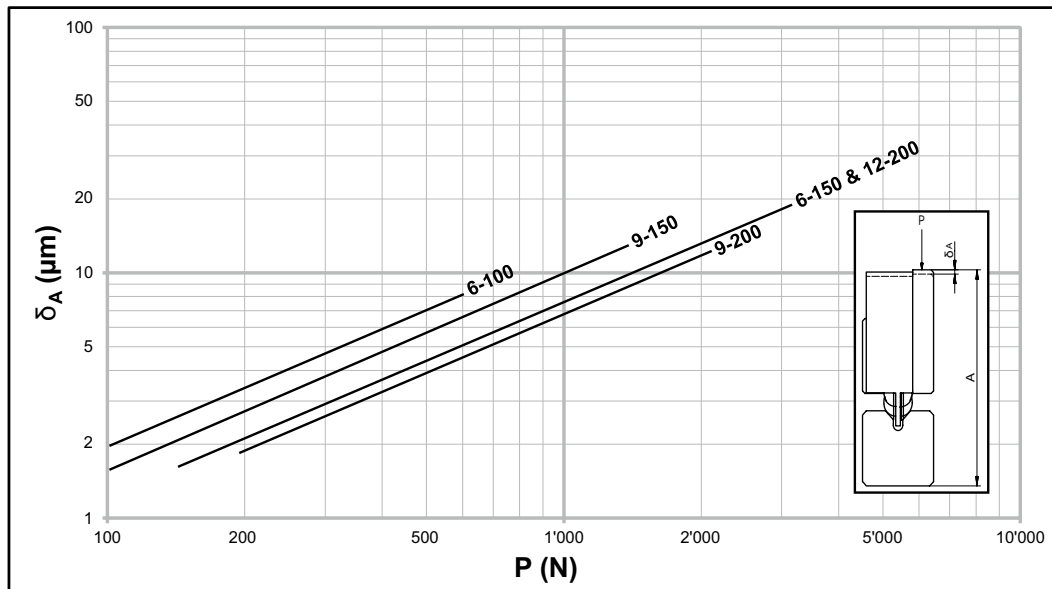
## 12 Load carrying capacity and service life

### 12.6 Elastic deformation and rigidity of recirculating units

The elastic deformation of the recirculating unit of type SK in connection with linear guideways type R or RD.

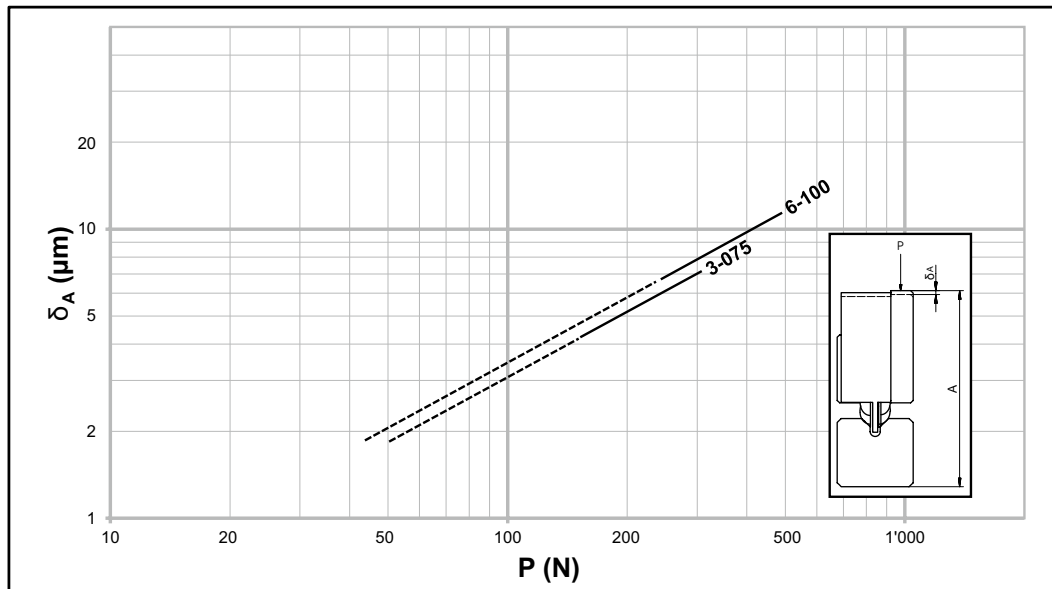


The elastic deformation of the recirculating unit of type SKD in connection with linear guideways type R or RD.

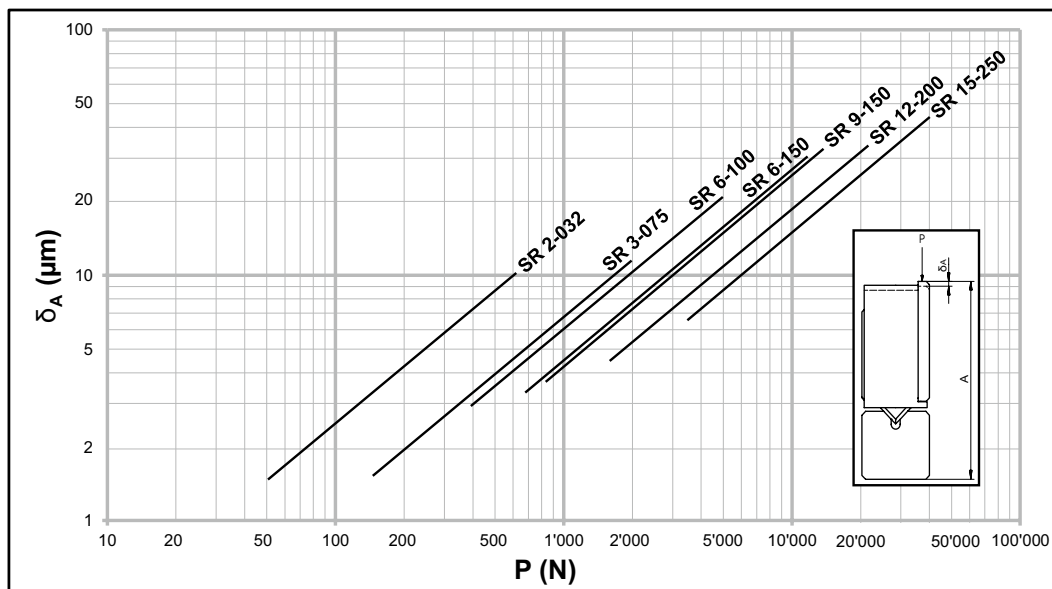


## 12 Load carrying capacity and service life

The elastic deformation of the recirculating unit of type SKC in connection with linear guideways type R or RD. The total length of the straight lines applies for lubricated recirculating units, the dotted straight line for unlubricated ones.



The elastic deformation of the recirculating unit of type SR in connection with linear guideways type R or RD.



## 12 Load carrying capacity and service life

The elastic deformation of the recirculating unit type NRT.

