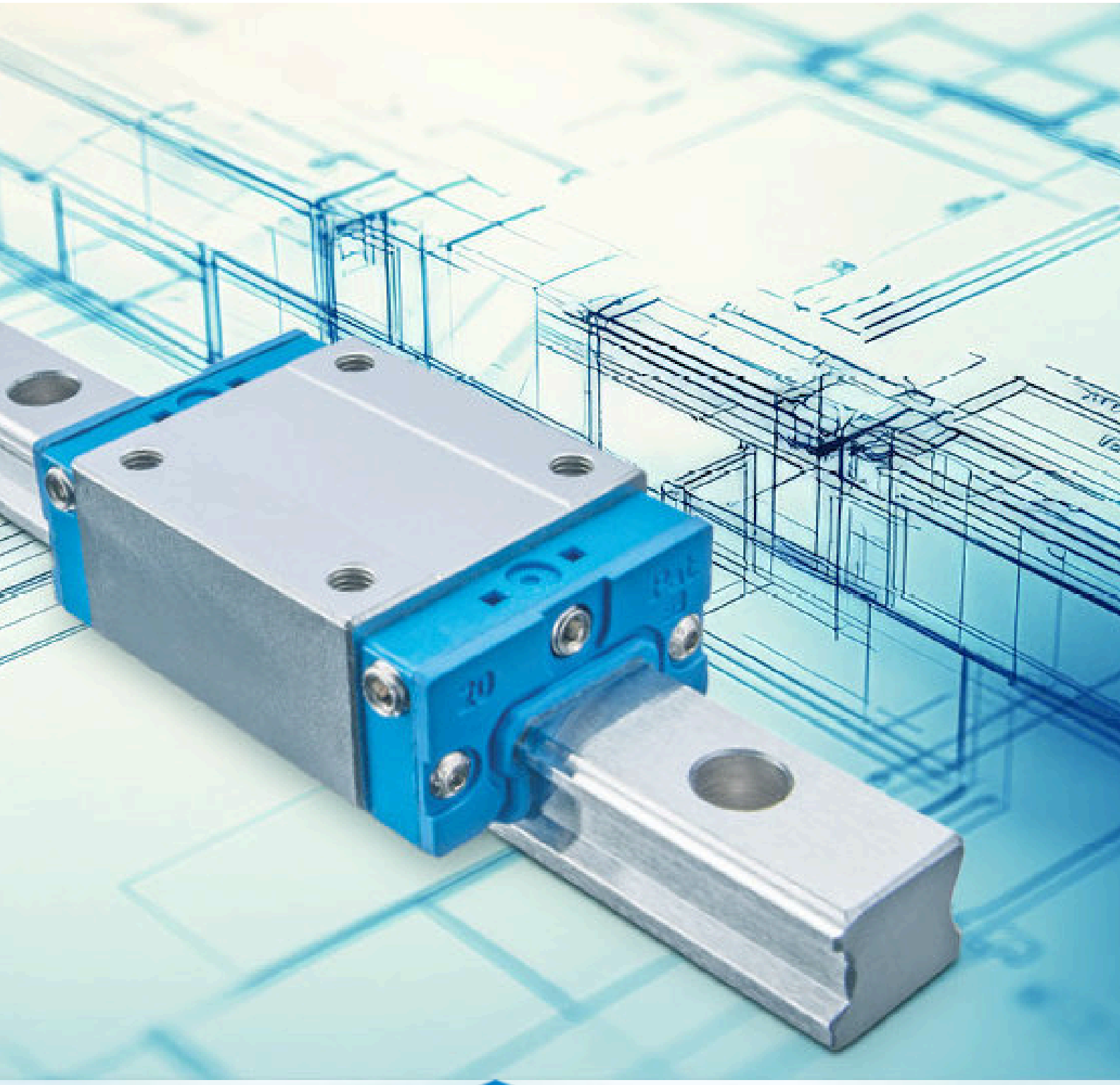
NTN

ALL ABOUT LINEAR MOTION



linearwizard.com

Calculation principles (ball bushings)

linearwizard.com

If you have already clicked through the texts on the calculation principles for linear guides and screw drives on linearwizard.com, you will already know that various factors and formulas must be taken into account when designing linear systems. This is no different for ball bushings, which is why you will find everything that is important for their calculation in this article. The topics range from tolerances, load ratings, the static safety factor, maintenance and lubrication to the calculation of the nominal service life.

Tolerances

With ball bushings, the amount of clearance on the shaft must always be considered. Depending on which standard the ball bushings comply with (ISO or JIS), the enveloping circle tolerance of the ball bushing varies. For the same shaft fit, as can be seen in the table using the example of a ball bushing ⌀ 20, the radial clearance varies. Due to the different standards on which ball bushings can be based, preload and clearance are possible on the same shaft. This means, for example, that one ball bushing can tilt due to clearance, while another runs completely without clearance or with preload. It should also be noted that ball bushings are generally less suitable for applications that require preload; in such cases, linear guides are a better alternative.

	Ball Bushing ø 20			Shaft ø 20 h6
	ISO Ball Bushings	JIS Ball Bushings		
Enveloping circle tolerance	-1...+9 µm	-10...0 µm	Outer diameter	-13...0 µm
	19,999...20,009 mm	19,990...20,000 mm		19,987...20,000 mm

The inside diameter of JIS ball bushings in the given example is a few µm smaller than that of ISO ball bushings.

	ISO Ball Bushing		JIS Ball Bushing	
Minimum enveloping circle	19,999 mm	1 µm Preload	19,990 mm	10 µm Preload
Maximum shaft ø	20,000 mm		20,000 mm	
Maximum enveloping circle	20,009 mm	22 µm Radial clearance	20,000 mm	13 µm Radial clearance
Minimum shaft ø	19,987 mm		19,987 mm	

As can be seen in this table, both preload and clearance are possible with ISO and JIS ball bushings due to the tolerances with regard to the enveloping circle and shaft diameter.

Load ratings

Both the static and dynamic load ratings of ball bushings are calculated in accordance with DIN ISO 14728-2. The static load rating C_0 describes the constant axial load that generates a total plastic

deformation of 0.00001 times the ball diameter.
The dynamic load rating C_a refers to an axial load that is not variable in size and direction and at which a ball bushing achieves a nominal service life of 5×10^4 meters.

The static safety factor f_s

For ball bushings, it is also important to calculate the static safety factors f_s in order to avoid impermissible plastic deformations caused by load peaks. These events, which are difficult to predict, occur due to impacts and blows to the ball bushings, for example.
The static safety factor f_s is the ratio of the static load rating C_0 to the maximum occurring load F_{0max}. This refers to the highest amplitude; even very short-term amplitudes are considered. The function of the static safety factor f_s is to prevent impermissible plastic deformation of the raceways and rolling elements.
To calculate the static safety factor f_s, the static load rating must be divided by the maximum equivalent load. The value of the static load rating can be influenced by three additional factors, the contact factor f_c, the hardness factor f_H and the temperature factor f_T.

Formula 9

$$f_s = \frac{f_H \times f_T \times f_C \times C_0}{F_{\max}}$$

f_s	Static safety factor
f_c	Contact factor
f_H	Hardness factor
f_T	Temperature factor
C_0	Static load rating [kN]
F_{max}	Maximum equivalent load [kN]

The formula for the static safety factor f_s is identical, regardless of whether you calculate it for ball bushings or linear guides.
The contact factor f_c is used if several ball bushings are located at a small distance from each other. In this case, it is assumed that not all ball bushings can absorb the same load due to assembly tolerances. It must therefore be assumed that the load absorption is generally lower than theoretically possible.
The hardness factor f_H changes the static load rating if ball bushings are made of a material that does not achieve the same hardness as rolling bearing steel. This applies to stainless steel, for example.
temperature factor f_T in turn, is used at operating temperatures above 100 °C. At temperatures above this limit, the hardness of the steel of the ball bushings decreases.

The nominal service life L

The nominal service life L bdescribes the mileage that a ball bushing covers before the first signs of material fatigue appear. It is generally calculated in meters. The same formula is used here as for calculating the service life of linear guides; this is based on a calculation of 5×10^4 meters. In practice,

however, the service life of ball bushings is rarely calculated.

Formula 10

$$L = \left(\left(\frac{f_H \times f_c \times f_T}{f_w} \times \frac{C}{F_m} \right)^3 \times 5 \times 10^4 \right)$$

L	Nominal service life (m)
C	Dynamic load rating (kN)
f_H	Hardness factor
f_c	Contact factor
f_T	Temperature factor
f_w	Load factor
F_m	Mean equivalent load

Two birds with one stone: You only need to know one formula to calculate the service life of linear guides and ball bushings.

It is important to note that the operating conditions play a central role in the design of f_w factor. The intensity of vibrations and shocks is of particular importance. A distinction is made between five levels and the more challenging the environmental conditions, the higher this load factor must be.

Operating conditions	Speed (m/s)	Load factor
No or very low vibrations and shocks	≤ 0.25	1.0 ... 1.2
Low vibrations and shocks	0.25 ... ≤ 1.0	1.2 ... 1.5
Medium vibrations and shocks	1.0 ... ≤ 2.0	1.5 ... 2.0
Strong vibrations and shocks	>2	2.0 ... 3.5
Short-stroke applications		3.5 ... 5.0

The factor f_w considers the presence of oscillations and vibrations and their negative influence on the service life of ball bushings.

As an alternative to the “meter“ unit, the nominal service life *L*10 can also be converted into hours (L_h) and cycles ($L_\#$). These two units are calculated as indicated.

Formula 11

$$L_h = \frac{L}{2 \times s \times n \times 60}$$

L_h	Nominal service life (m)
s	Stroke (m)
n	Number of strokes (min^{-1})

$$L\# = \frac{L}{2 \times s}$$

$L_\#$	Nominal service life (cycles)
s	Stroke (m)

Flexible: Depending on requirements, L is specified in kilometers, hours or cycles.

Maintenance and lubrication

As you may have already read in the article on the variants of ball bushings, most ball bushings do not offer the option of relubrication. If this is necessary, however, there are three lubrication types to choose from; lubrication is then possible either via a grease gun, an automatic lubricator or centralised lubrication systems or oil mist lubrication, whereby centralized lubrication systems or oil mist lubrication are used extremely rarely due to the very low lubricant requirement. The relubrication intervals and relubrication quantity must also be determined depending on the ambient conditions. The choice of the right lubricant is also of great importance – it must be noted that ball bushings must never be lubricated with a lubricant containing solid lubricants, as this very quickly leads to blockage of the ball recirculation and thus to failure of the ball bushings!

You may also be interested in

Basics of linear motion

Are you new to the field of linear motion and want to get an overview of what is meant by “linear motion“ and what characterises linear systems? Then this article is perfect for you. What is a linear system? A linear system is a machine component that performs a translational movement. To ensure safe use and prevent the ingress of
Read more »

Types of ball bushings

Ball bushings, which are also known as “linear ball bearings“, are an important product in linear motion. This article deals with the different variants of ball bushings and their properties but first provides you with basic information regarding their history, characteristics and design.
Read more »

Types of screw drives

You may have heard of ball screws before. These are certainly the best known of the screw drives, but they are not the only ones, as trapezoidal screw drives are a second type. This article will focus on the former, but you will still find everything you need to know about both types here. Design, mode of operation and areas
Read more »

Types of linear guides

Linear guides are presented below as one type of linear system. Linear guides are among the most important guide systems on the market, mainly because they can be used universally. Types of linear guides A distinction is mainly made between two types of linear guides: Shaft guides and rail guides. Both can be subdivided into different types. Types of shaft
Read more »

Materials

This article is the right address for you if you want to find out more about the materials used in linear systems. First of all, all components that need to be robust are made of steel, including the rolling elements, the guide rails and the carriages. General information on the materials In addition to steel, various other materials are used
Read more »

Point, surface and line contact

If you have already dealt with the point and linear contact of rolling bearings, you will recognise a few things. As with rolling bearings, the rolling elements of linear guide systems have either a ball or roller shape. The contact with a raceway (rolling contact) is different for balls and rollers due to their round or elongated shape. With rolling
Read more »

Make the world **NAMERAKA**

SCAN THE QR-CODE
AND DISCOVER
ROLLING BEARING
KNOWLEDGE

NTN Wälzlager GmbH compiles the information for this website with great care and endeavors to ensure that it is up-to-date, correct and complete. SNR Wälzlager GmbH accepts no liability and is not liable for any material or non-material damage caused by the use of the service, unless it can be proven to be the result of intent or gross negligence.

© NTN Wälzlager GmbH
NTN Europe - 1 Rue des Usines, 74010 Annecy
www.ntn-snr.com

NTN | SNR | BCA BEARINGS | BOWER | Brands of NTN corporation