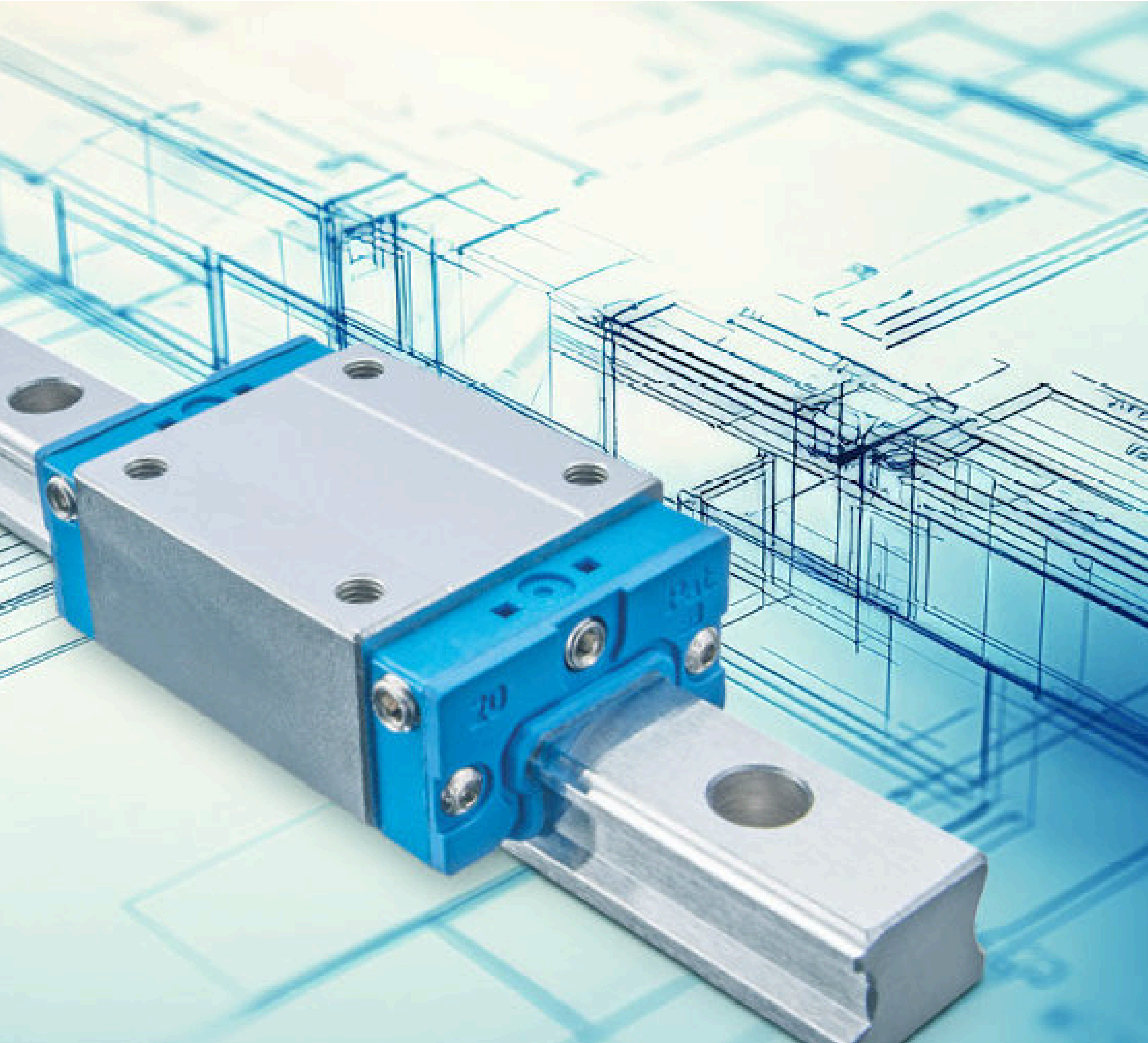
NTN

ALL ABOUT LINEAR MOTION



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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?

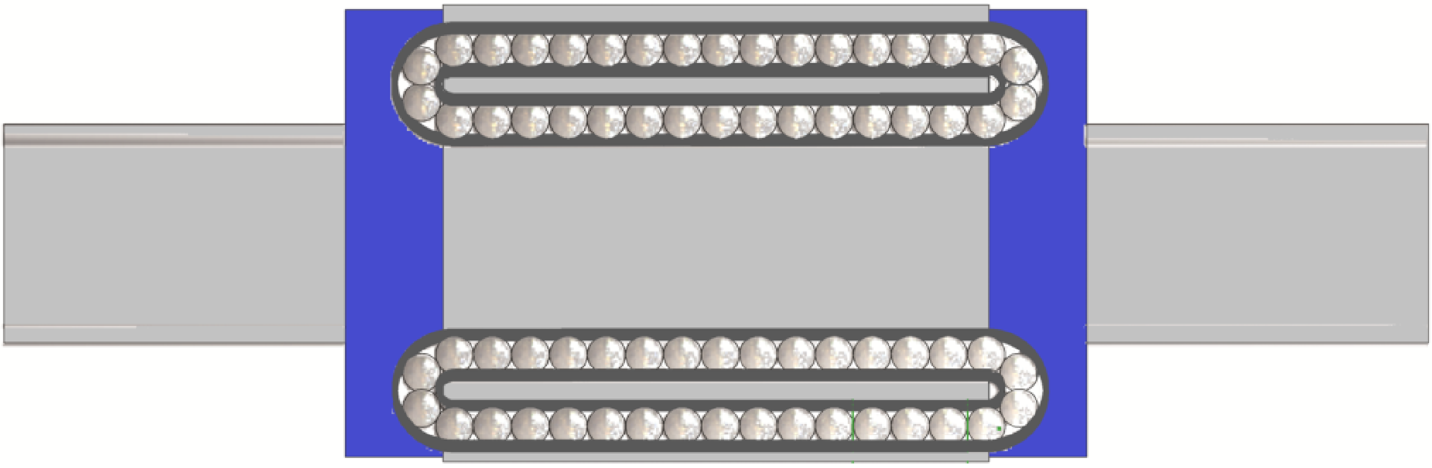
A linear system is a machine component that performs a translational movement. To ensure safe use and prevent the ingress of dust, the entire linear system must be protected by a cover and suitable wipers. A linear guide system is – similar to a rolling bearing – equipped with rolling elements in ball or roller form. Linear motion comprises various products, including linear guides, linear axis, ball screws, ball bushings and ball splines. Today’s linear systems are characterised by the fact that they can be used with low friction, low energy consumption and low noise levels.

Linear guides are the most important linear guide systems on the market today.

Structure and mode of operation

The theories of linear motion are comparable to those of rotary technology. You just have to imagine that a linear guide is unfolded in comparison to the rolling bearing. As in the rotative area, there are rolling elements, raceways in the guide rail and carriage and optionally ball or roller chains, whereby the latter are functionally comparable to cages in the rotative area. Linear guide systems with recirculating ball or roller guides consist of carriages that move along guide rails. In addition to these basic components, other components include end seals, seals on the underside and inside as well as accessories such as cover strips, rail caps and grease nipples.
The rolling elements of a ball or roller guide roll on the raceways of the profile rails and carriages and are deflected in the carriage. The carriages run on the rail with very low friction. Linear guides allow very high loads to be moved with little effort and nearly no stick-slip effect. This is due to the very low coefficient of friction μ of approx. 0.003. When a rolling element reaches the end plate of a carriage, it is deflected there and guided back into return holes within the carriage. This means that a rolling element can roll an infinite number of times in this rhythm – a single cycle! Several (and theoretically an unlimited number of) carriages can be mounted on one guide rail. The rolling elements can be kept at a distance from each

other by the ball chains.



In addition, the rolling element recirculation of the carriage consists of a forward and return run. The rolling elements in the forward line are under load, while those in the return line are not. For this reason, the forward line is also known as the “load zone“.

Areas of application for linear systems

The fields of application for linear motion are just as diverse as in the rotary sector. Today, linear guide systems are used in countless industrial applications, including the electronics and semiconductor industries, machine tool manufacturing, automation technology, packaging machines and woodworking machines. Other areas of application include production machinery, robotics and aircraft and automotive manufacturing. Linear guide systems favour high speed and precision in these applications. In recent history, other areas have also come to rely on linear systems, including battery and solar cell production. Linear guide systems are also used in building technology, including (automatic) sliding doors and ventilation flaps. In the general mechanical engineering, linear guide systems are primarily used to realise infeed and feed movements. Some areas of application are presented in detail below.
Linear motion is indispensable in robotics. Robots are used in factories, for example, to transport products and/or perform pick-and-place movements. Robots often move on linear guides. They often have to be adapted to high requirements, for example when they are exposed to heavy soiling or transport heavy loads. Robots in which linear guide systems are installed are not only used in automation: other examples of applications include pick-and-place machines, stacking systems or automated sewing machines. Linear motion is also used in robots with a seventh axis – i.e. an axis on which the entire robot moves. Thanks to the seventh axis, the robot can extend its range of action almost at will.

Another example is machine tools. Linear guides are used in various types of machine tools such as machining centres, turning and milling machines. High precision and rigidity of the linear guide systems are key requirements here. Linear guide systems enable the compact design of a machine tool, high performance and a relatively long service life. The machines – and therefore also the linear guide systems – must be powerful enough to withstand the reactive forces involved in machining metal workpieces.

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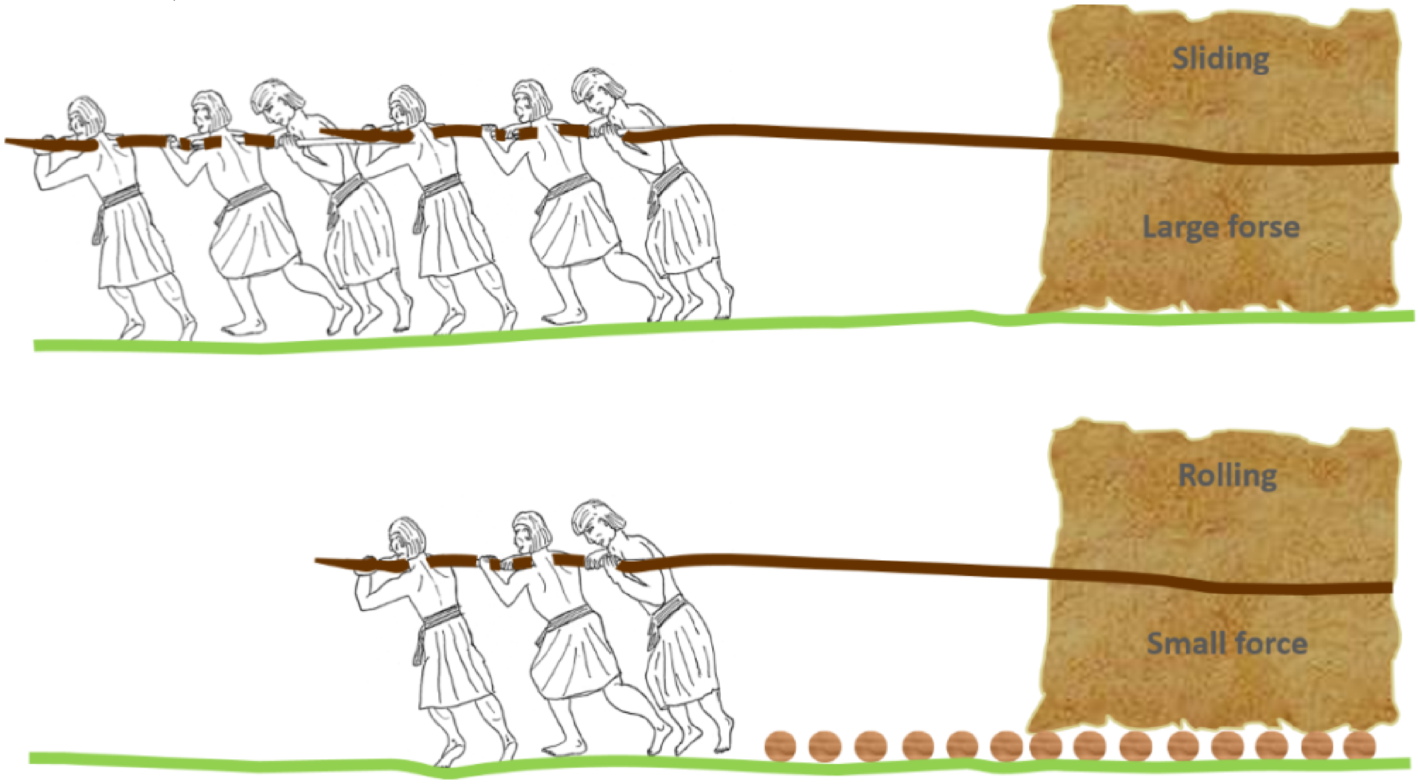

Heavy loads were rolled on timbers around 2500 BC in order to minimise friction during transport.

Linear motion in the age of industrialisation

Out of ancient Egypt and into the age of industrialisation: The increased use of linear guide systems became necessary as a result of the mass production of industrial machines, when the increased requirements for speed, precision, smoothness and efficiency had to be met. Linear guide systems followed rolling bearings, which are used for rotating movements. In addition, balls as rolling elements were installed in linear systems. The development of modern linear guide systems can be considered a milestone.
In 1944, a ball bushing – as it is commonly known today – with recirculating balls on a round shaft was developed in the USA. Based on this bushing, work was carried out on the development of a linear guide with a raceway adapted to the rolling elements. The first linear guide, a profiled rail guide, was presented in 1972. . An important point was finally reached in 1993, when the company began to manufacture linear systems with rolling elements in both ball and roller form. Three years later, in 1996, a linear guide with ball

chains was presented.

Linear motion today

The way in which heavy loads are transported has changed significantly since ancient times. Nevertheless, modern linear motion is still inspired by the first approaches from ancient world. The rolling elements that are installed in linear guides, for example, move in a closed circulation in today's linear guide systems. In addition, high demands are placed on linear motion today: the products must fulfil various standards, for example in terms of precision, rigidity and load capacity. In addition to linear guides, there are now other types of linear guide systems, including linear axis, ball screw drives and ball bushings. Today's linear guide systems are also used in a wide variety of applications such as machine tools, sliding doors, packaging or woodworking machines: These days, they are indispensable.

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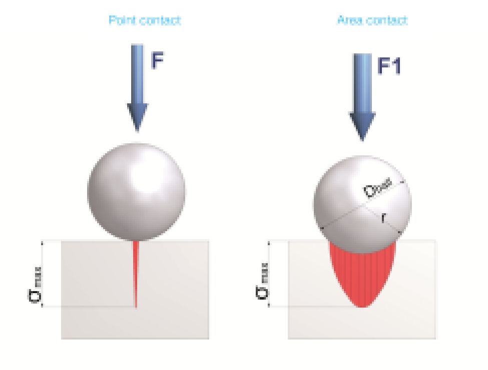
Point contact

Point contact is characterised by a small contact surface between balls as rolling elements and a flat or strongly convexly curved surface, whereby this contact surface has a circular structure. It therefore occurs in linear guide systems which have no profiling. This applies, for example, to ball bushings or ball sleeves, where the balls roll on a large shaft diameter. The advantages of point contact are minimized friction and a comparatively low lubricant requirement. However, the logical consequence of the small rolling contact is a high surface pressure compared to surface and line contact with the same load. For this reason, applications with point contact can only accommodate relatively small loads with comparatively low rigidity. Point contact is the conventional type of rolling contact for balls as rolling elements.

Surface contact

In abstract terms, surface contact is a modified, large point contact and represents an alternative to this. With the aim of increasing the contact surface, the raceways of certain linear guide systems, for example linear guides, are manufactured with a specific radius. The ratio of the ball diameter to the radius of the raceway is called osculation. In other words, raceways with a defined osculation are used instead of flat raceways so that the ball makes flat contact with the raceway. The osculation usually used results in a contact surface that is 13 times larger compared to point contact, which means that 13 times more load can be applied to each ball. In addition to the higher load capacity, further advantages compared to point contact are the higher rigidity of the balls and the reduction in surface pressure. Last but not least, the improved force distribution with surface contact ensures a longer service life for the rolling elements and the linear guide system itself.



δ_{max} maximum surface pressure

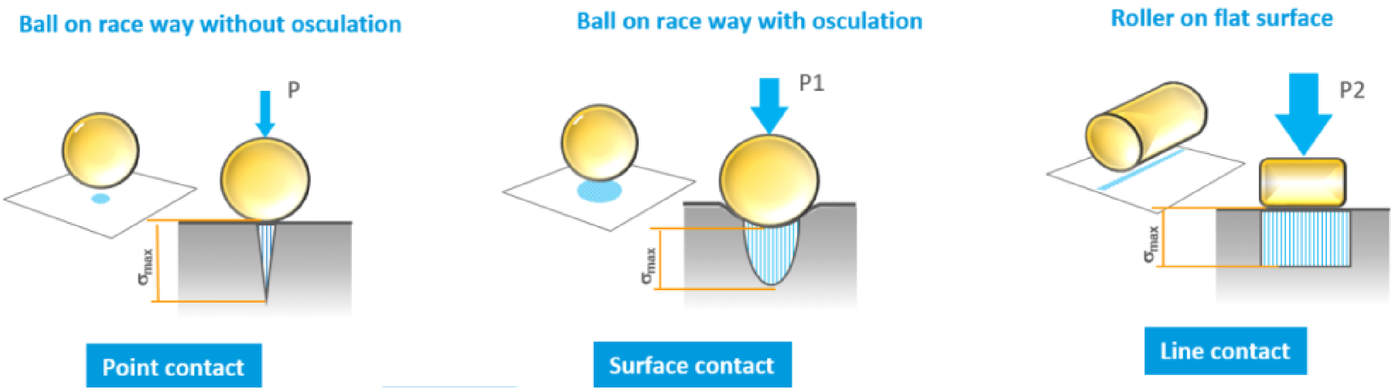
D_{ball} Ball diameter

r Race way radius

The surface contact as a modified point contact: With the same permissible surface pressure, the surface contact has a significantly higher possible load F1 compared to the point contact.

Line contact

The name says it all: unlike point and surface contact, the contact surface of line contact is linear. Line contact occurs in all linear guide systems with cylindrical rolling elements, for example in roller guides, recirculating roller bearing units and flat cage guide systems. Line contact is characterised by its ability to absorb higher loads than point and surface contact. It is also characterised by greater rigidity, in this case you can imagine the rolling element as a stiff spring: The roller guides have a significantly higher rigidity than the ball guides. At the same time, the load is distributed over a larger area with line contact, which is why the surface pressure is lower than with point or surface contact for the same load.



With balls as rolling elements, there are two types of rolling contact: point contact and surface contact, whereas rollers always have line contact.

Roller profiles

The profile of the rollers can be described as cylindrical. Although the rollers are crowned to a very small extent, the radius is so large that this is hardly significant. Because roller guides – unlike roller bearings –

do not have a fixed cage that prevents the rollers from tilting, this crowned shape is used here to minimise the effect of edge pressure.

In addition to rigidity, higher load ratings are the decisive reason for choosing a linear guide system with cylindrical rolling elements. The disadvantage of these rolling elements compared to balls is a lower permissible travel speed and significantly lower permissible mounting tolerances of the linear guide systems.

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General information on the materials

In addition to steel, various other materials are used in linear guide systems. These include plastic and synthetic rubber. The table summarizes the most important materials and their use.

Material	Components
Steel	Rolling elements, guide rails, carriages, screws, grease nipples (for relubrication) and special end plates
Plastic	End plates, cage parts and ball chains
Synthetic rubber	Seals/wipers

Super important: High-quality steels are the be-all and end-all of linear motion materials.

As in the rotative area, the appropriate lubrication of linear guide systems has an existential function. In addition, all materials used, especially plastics and lubricants, must be adapted to the permissible operating temperatures and application parameters. The specific operating conditions must be considered when using the respective materials. In case of doubt, the respective manufacturer should be consulted regarding the temperatures and components.

Steel in rolling elements, guide rails, carriages and screws

In the rolling elements of linear systems, carbon steels standardized according to ISO or JIS, for example with the designation 100Cr6 (according to JIS: SUJ2), are used, which were originally developed for rolling bearings. The steel 100Cr6 is the worldwide standard material for rolling bearings as well as for rolling elements and is also used in a similar form in linear motion.

The guide rails in linear guide systems have a profiled square or rectangular cross-sectional shape. Their raceways are generally edge-hardened under a high-frequency current (inductive). This means that the rails are guided linearly past the inductor and hardened in the process – not through-hardened! However, small sizes can also be through-hardened.

The carriages are made of low-carbon chrome steel, which is relatively easy to machine. Machining is followed by carburizing, which involves hardening the steel under heat. Smaller carriage designs are through-hardened for production reasons. Hardened, rust-resistant steel is used in environments with an increased risk of corrosion; this also applies to rolling elements and guide rails.

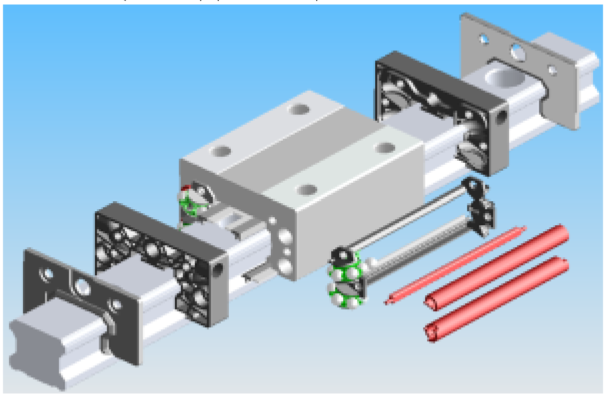
Numerous screw types and sizes can be used in linear guide systems. The screws are often made of alloy steel. If corrosion protection is required, coated steel screws are also used. Due to their robustness, hexagon socket screws are used to fix rails and carriages. There is a hexagonal pillar hole in the center of their cylindrical head.

Plastics for end plates, cage parts and ball chains

Plastics in linear systems are used for the end plates, cage parts, ball chains and rail caps (brass caps are also available as an alternative). Plastics offer the possibility of being injected into metal moulds, so that even complex shapes can be produced relatively quickly. However, it should be noted that some types of plastic melt at high temperatures.

Synthetic rubber seals

Synthetic rubbers are elastic to ensure good contact with the rail and offer comparatively high resistance to oil and wear. They also have a long service life but a limited operating temperature. The three relevant materials for synthetic rubbers are NBR, ACM and Viton. In addition to the standard version, there are seals for special conditions, for example those characterized by excellent resistance to chemicals and heat (this applies in particular to the material Viton).



Unlike rolling bearings, each component in linear motion has a fixed material that does not vary.

You can find information on the materials used for rolling bearings here. If you would like to find out more about the various linear guide systems, click through the articles on linearwizard.com that deal with the types of linear guides, screw drives, linear axis and ball bushings.

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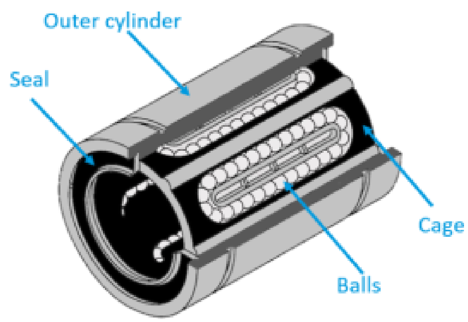
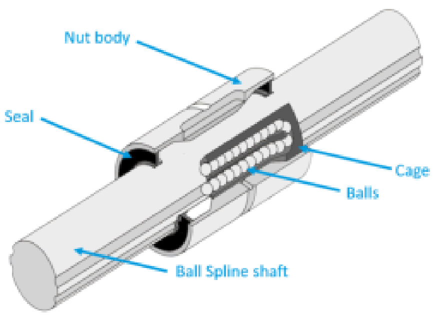
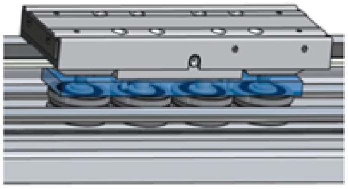
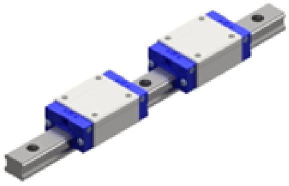
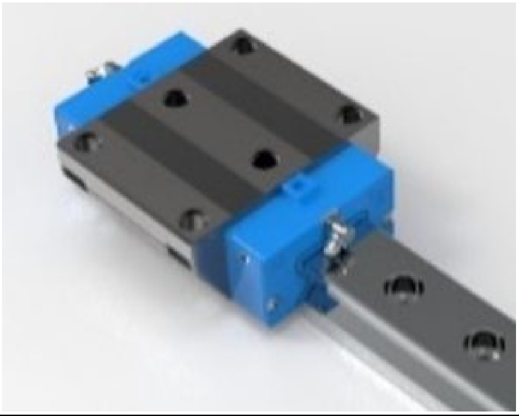
A distinction is mainly made between two types of linear guides: Shaft guides and rail guides. Both can be subdivided into different types. Types of shaft guides are ball bushings, ball cage guides and ball splines. There are four main types of rail guides, also known as *profiled rail guides*, including track roller guides, flat rail guides, ball guides and roller guides. Some of these can be further differentiated; the following table provides a general overview.

Kind	Types	Picture	Subtypes
Shaft guides	Ball bushings		• Standard ball bushes • Super ball bushings • Ball sleeves
	Ball cage guides		
	Ball splines		

Rail guides	Track roller guides		
	Flat sliding guides		• Re-circulating roller bearing units
			• Ball, roller or needle cages
	Ball guides		• Ball guides without/with ball re-circulation or • Number of raceways (2, 4, 6 or 8) or • Arrangement of the raceways (DF or DB) or • with/without ball chain The distinctions can be applied individually. Several criteria may also apply.
	Roller guides		• Roller guides with/without roller re-circulation or • Arrangement of the raceways (DF or DB) or • with/without roller chain The distinctions can be applied individually. Several criteria may also apply.

If you are not only interested in the types of linear guides, but also in the calculation principles that need to be taken into account and how they are installed, you will find the relevant articles on linearwizard.com.

Shaft guides

All shaft guides have balls as rolling elements and have point contact with round shafts or surface contact with the raceway of ball spline shafts. They are generally used for axial movements.

Ball bushings

Ball bushings are also known colloquially as “linear ball bearings”. As they do not have a raceway in the associated shafts, the rolling contact is a point contact. Standard ball bushings consist of a solid outer cylinder behind which the balls and cage are located, and super ball bushings consist of a plastic base body in which steel parts with the raceways are inserted. An (incorporated) seal can also be used. Ball bushings are often used in computers, (3D) printers and in the packaging industry, for example.

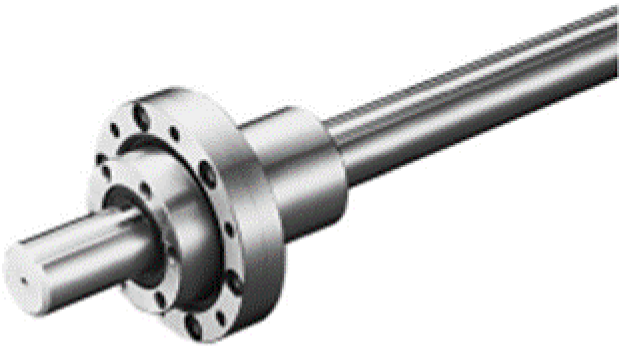
Ball bushings are available in numerous versions, designs and lengths, including closed (image), open, adjustable and super ball bushings.

Ball sleeves have a similar system to standard ball bushings, particularly in terms of structure and function. While the former has a solid outer body, ball sleeves are made from deep-drawn sheet metal, which is why they can be more cost-effective than ball bushings.

Ball cage guides

Ball cage guide systems also have balls as rolling elements. They are characterized by precision in movement and are capable of high loads. As ball cage guide systems do not have recirculating balls, the movements are absolutely smooth and jerk-free. Applications for ball cage guide systems include column guides for presses, as well as applications in measurement technology.

Ball splines



The ball spline shaft on which they are mounted gives the ball splines their name.

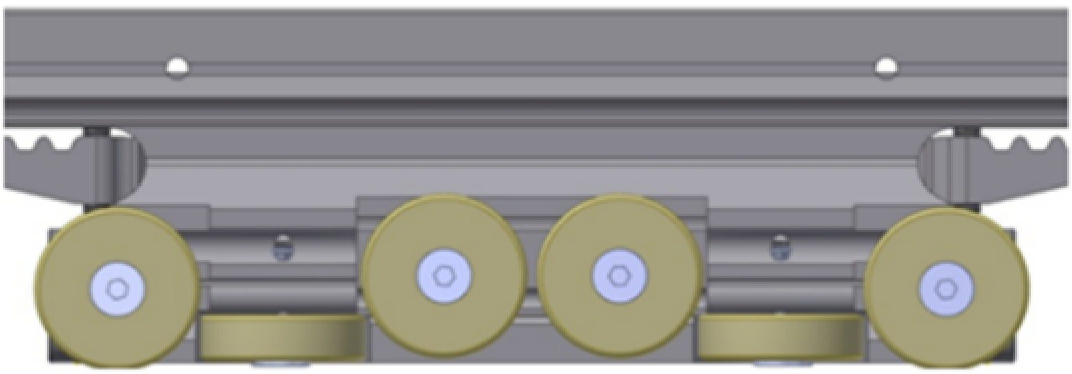
Nuts of ball splines are mounted on a shaft that has raceways for balls. In addition to the ball spline shaft, another important component is a nut body in which the balls and cage are located. A seal can be used as an option. Ball splines have raceways ground into a round shaft. This means that the rolling elements of the ball splines have surface contact with the raceway. Ball splines are used, for example, in the packaging or printing machine industry.

Rail guides

Rail guides can be divided into four main types (track roller guides, flat rail guides, ball guides and roller guides), some of which are further differentiated.

Track roller guides

The carriages of track roller guides contain specially moulded track rollers. The track roller is comparable to roller bearings, but with a profiled outer ring. Ground shafts pressed into an aluminium rail or solid steel rails can form the track of the track roller. The advantages of track roller guides over linear guides are very high speeds with relatively low friction and the fact that they are generally considered to be cost-effective. Track roller guides are used in automation technology (robots, conveyor belts), in safety doors on machine tools and in medical devices.



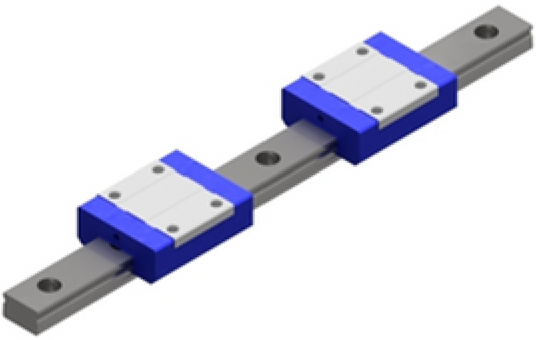
One of the alternatives to the standard version is the polymer roller guide shown here.

Flat rail guides

Flat guides include recirculating roller bearing units, which are rarely used today, as well as ball, roller or needle roller cages. Recirculating roller bearings have a cylindrical rolling element, so there is line contact with the raceway. The rollers move around a supporting body that has a guide rib in the direction of travel. Recirculating roller shoes have a theoretically unlimited stroke. They have a high load capacity and high rigidity but can only absorb forces in the radial direction. In the past, recirculating roller bearing units were used in applications where the highest load capacity and rigidity were required, such as in machine tools. Ball, roller and needle roller cages keep the rolling elements at a distance from each other and thus prevent mutual contact; they also have the task of guiding the rolling elements parallel to the axis and thus minimizing the effects of misalignment. Needle roller and cage assemblies are ideal for applications with high loads. Their main advantage is that they are light and compact, which means they require little installation space. Due to their design, cage guides have a limited stroke. All cage guides also have relatively low friction and move absolutely smoothly. They are used in laboratory equipment, microscopes and measurement technology.

Ball guides

The rolling elements of ball bearing guides are balls and have surface contact with the raceway. In terms of their characteristics, they cannot be divided into different subtypes, unlike most of the previously mentioned types of linear guides. Versions of ball guides are categorized according to their design, with one or more of the following distinctions being applicable. Ball guides are available with and without recirculating balls. If they do not have a recirculating of balls, the rolling elements travel half the distance of the table, whereas if they have a recirculating ball bearing, the rolling elements move in a closed circuit in the carriage. There are differences from ball guide to ball guide in terms of their raceways; they can have two, four, six or eight raceways. In addition, the raceways can be arranged in a DF or DB arrangement (NTN only offers ball guides with the raceway arrangement in DF). It is also possible to use the ball guides with or without a ball chain. are areas of application in almost all branches of industry, particularly in machine tool construction, automation technology, the woodworking industry and semiconductor and electronics production.



A linear guide with ball chain is shown here.

Roller guides

As their name suggests, roller guides have rollers as rolling elements. The rolling contact is therefore a line contact, which means that roller guides are highly resilient and have a higher level of rigidity compared to ball guides. They can be used with or without roller recirculation (comparable to ball recirculation, see the previous paragraph for more information). As with ball guides, raceway arrangements in DF or DB arrangement are possible, and roller guides can also be designed with or without a roller chain. In applications that require a high load capacity and high rigidity at the same time, it is advisable to use roller guides, for example in machine tools.

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Calculation principles (linear guides)

As with rolling bearings, certain calculation principles must also be mastered in linear motion in order not to expose the linear guides to excessive loads and to prevent failures, a shortened service life and as well the oversizing of linear guides. It is therefore essential, for example, to calculate the service life of linear guides. Other calculations relate to the static safety factor or stiffness.

The nominal service life L_{10}

The servie life L refers to the mileage that a component can cover before the first signs of material fatigue, which are usually visible on the raceways or the rolling elements, appear.
You may already be familiar with the nominal service life L_{10} from the service life calculation of rolling bearings. It is based on a statistical calculation. L_{10} describes the calculated service life; it refers to a single linear guide system or a group of identical linear guide systems that run under the same operating conditions and can achieve the calculated service life with a 90 % probability of failure. If you want to reduce the failure probability of 10 %, you can achieve this goal through different dimensioning. However, this can easily lead to overdimensioning of the linear guide systems. To avoid such overdimensioning and design errors, it is advisable to consult the manufacturer in the event of uncertainties.
The nominal service life L_{10} of linear guides is specified in kilometres. The service life of ball guides is calculated slightly differently to that of roller guides; depending on the type of linear guide, one of the two formulas must always be used.

Formula 1

for ball guides:

$$L = \left(\frac{f_h \times f_c \times f_t}{f_w} \times \frac{C_{50}}{F_m}\right)^3 \times 5 \times 10^4$$

or

$$L = \left(\frac{f_h \times f_c \times f_t}{f_w} \times \frac{C_{100}}{F_m}\right)^3 \times 10^5$$

$$C_{100} = 1,26 \times C_{50}$$

for roller guides:

$$L = \left(\frac{f_h \times f_c \times f_t}{f_w} \times \frac{C_{100}}{F_m}\right)^{10/3} \times 10^5$$

L	Nominal service life (m)
C_{50}	Dynamic load rating based on 50 km (kN)
C_{100}	Dynamic load rating based on 100 km (kN)

f_h	Hardness factor
f_c	Contact factor
f_t	Temperature factor
f_w	Load factor
F_m	Average equivalent load

When calculating the service life, different formulae must be used depending on the type of linear guide.

As indicated above, the operating conditions are a factor that should not be neglected when calculating the service life. The intensity of vibrations and shocks is of particular importance, and a distinction is made between five levels.

Operating conditions	Speed (m/s)	Load factor f_w
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	>2.0	2.0...3.5
Short-stroke applications		3.5...5.0

As in the rotative area, oscillations and vibrations can have negative effects on the contact surface between the rolling element and the raceway.

Depending on the requirements, the nominal service life L_{10} can also be specified in units other than kilometres. It is possible to convert the unit into hours L_h or cycles $L_\#$.

Formula 2

$L_h = \frac{L \times 10^3}{2 \times s \times n \times 60}$		$L_\# = \frac{L}{2 \times s}$	
L_h	Nominal service life (h)	$L_\#$	Nominal service life (cycles)
s	Stroke (m)	s	Stroke (m)
n	Number of Strokes (min^{-1})		

In contrast to $L_\#$, the number of double strokes or cycles (min^{-1}) must be considered when converting to L_h.

The dynamic load rating *C*

According to DIN ISO 14728-1, the dynamic load rating *C* describes a radial load that is not variable in size and direction and that a linear guide can theoretically absorb for a nominal service life of 5×10^{10} m travelled distance. The following applies: If a nominal service life of 10^5 is assumed, the dynamic load rating for a nominal service life of 5×10^{10} m is multiplied by a conversion factor *1,26*. This conversion factor is also used to compare the load ratings. The formula for calculating the dynamic load rating is based on DIN ISO 14728-2.

The static load rating C_0

The static load rating C_0 is the static radial load in the centre of the most heavily loaded contact surface between the rolling element and the raceway. The static load rating C_0 corresponds to a calculated Hertz-type compression. According to DIN ISO 14728-1, this Hertz-type compression for linear guides is between 4 200 MPa and 4 600 MPa. This load results in a permanent overall deformation of the raceway. This deformation corresponds to approximately 0.0001 times the diameter of the rolling element (therefore the static safety factor f_s has to be always > *1*). The formula for calculating the static load rating C_0 is also defined in accordance with DIN ISO.

The static safety factor f_s

Another factor that needs to be calculated is the static safety factor f_s. This must be considered, as unexpected or unforeseen loads and/or torques can act on the linear guide system when designing linear guides. These can be due to various causes, primarily vibrations, shocks, short start-stop cycles (strokes) or overhanging loads.

The static safety factor f_s is the ratio of the static load rating C_0 to the maximum occurring load F_{omax}. This refers to the highest amplitude; even very short-term amplitudes are taken into account. The function of the static safety factor f_s is to prevent impermissible plastic deformation of the raceways and rolling elements. This factor also prevents cracks and fractures in the raceways.

Formula 3

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

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 static safety factor f_s must not be less than 1 but in practice is usually greater than 2 under normal operating conditions. The formula for the static safety factor f_s is also used for ball bushings.

Finally, a brief explanation of the three influencing factors, the contact factor, hardness factor and temperature factor, follows. The contact factor f_c considers the fact that the full load-capacity cannot be utilised if the carriages are arranged very close together or on block due to tolerances. From a distance between the carriages of two carriage lengths, the contact factor no longer has any influence and is 1.

The hardness factor f_H is always 1 at NTN. However, if a guide is not made from carbon steel like 100Cr6, but from a material with a lower hardness, a different value would have to be calculated.

The fact that the rail hardness is reduced in a temperature range of over 100 °C is considered with the temperature factor f_T . For applications with the corresponding temperature ranges, the temperature factor must therefore always be included in the calculation of the static safety factor f_S .

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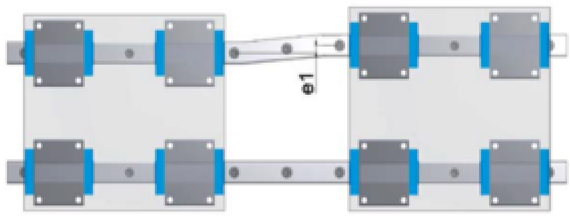
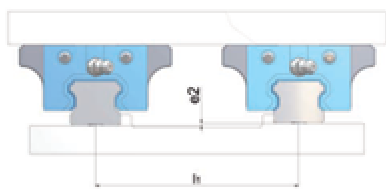
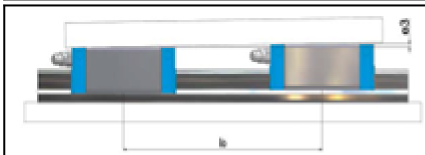
Are you planning to install a linear guide for the first time and don't yet have a clear overview of the process? Or have you already looked over someone's shoulder during assembly and want to make sure you know how the process works? This article focusses on the assembly and design of the mounting surfaces of linear guides – and of course, assembly instructions are also included!

Tolerances

A distinction is made between three assembly tolerances: the parallelism tolerance e1, the height tolerance between two rails e2 and the height tolerance in the rail direction e3. These are dependent on various criteria, which are listed in more detail in the table. Incidentally, linear guides with rolling elements in a DF arrangement offer more mounting tolerances than those with rolling elements in a DB arrangement,, as the former allow more deformation.

Montagetoleranz	depending on	Picture
Parallelism tolerance e1	• Size • Preload class	
Height tolerance between two rails e2	• Size • Preload class • Rail distance	
Height tolerance in rail direction e3	• Size • Carriage length • Preload class • Carriage distance	

All three assembly tolerances depend on the size and preload class, with e2 and e3 there are additional factors.

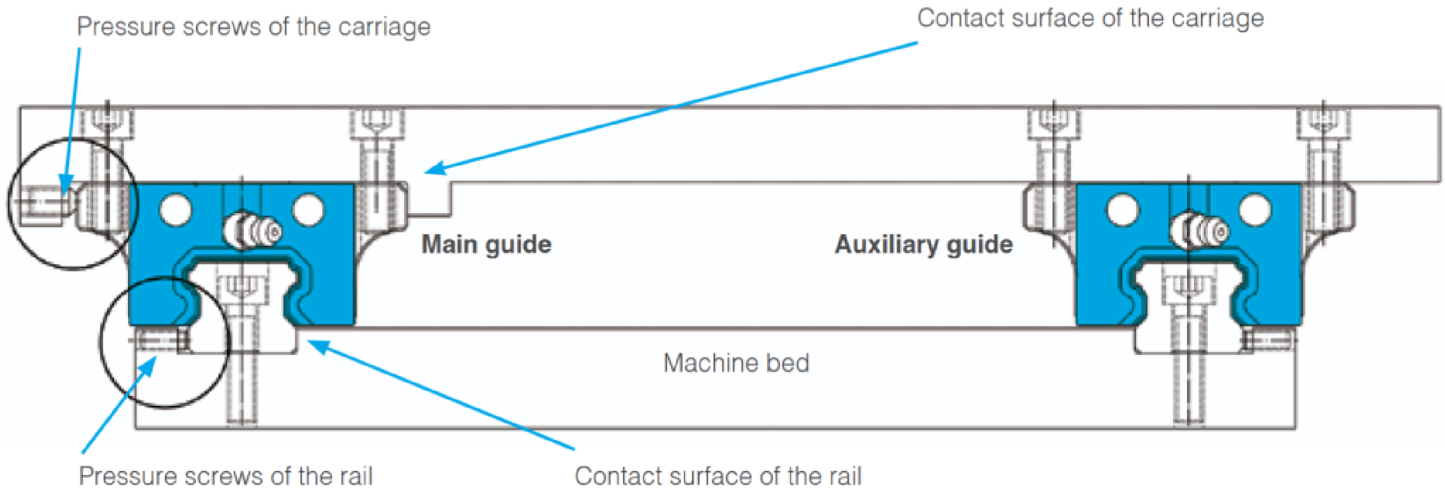
Marking of linear guides

SNR linear guides have two sides, one of which has important markings for identification purposes. The type designation and traceability code are indicated on this side, while the second side, the reference side,

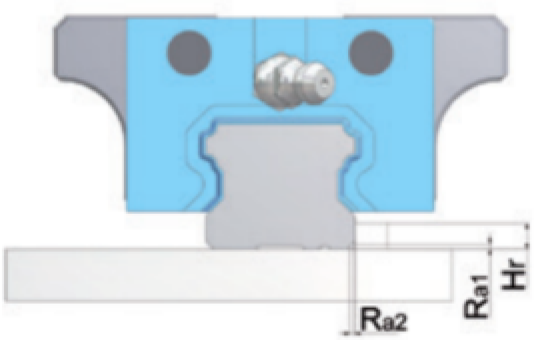
has a ground surface.
Rails have one or two grooves on the bottom; if there is one groove, this is the reference side; if there are two grooves, the side with the narrow groove is the reference side.
For asymmetrical rails, there are different definitions with regard to the position of the bore pattern depending on the rail arrangement. Jointed rails are labelled at the rail ends with “J”. During installation, it is particularly important to ensure that the rails run smoothly over the rail joint. As the tolerances of these rails are matched at the rail joints, the clear markings of the rail segments with “J” must always be observed in order to avoid confusion. All rail segments labelled with “J” can be combined as required. There is no fixed sequence for the segments.

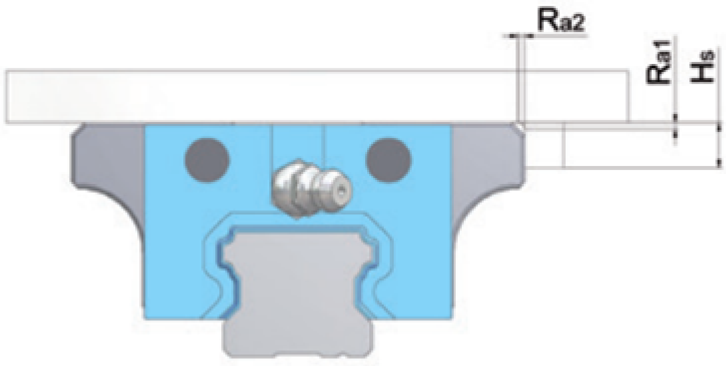
What needs to be considered when designing the mounting surfaces?

Linear guides are most commonly installed with two rails arranged in parallel; one or more carriages are mounted on each rail. In the picture, the rails are mounted next to each other on a flat surface such as a machine bed. The table is fixed to the carriages.



This example illustrates the assembly when using two linear guide systems arranged in parallel.
When a mounting surface is manufactured, a certain radius must be maintained. The contact edges must not exceed or undercut the connection geometries specified by the manufacturer: These dimensions have to be always taken into account so that the carriage does not touch down (jam) but still has a sufficiently large contact area. The primary function of the contact edges is to position the linear guide system precisely during assembly. The fact that assembly is generally simplified by using the contact edges should also be emphasized positively. For assembly, information is required regarding the height of the contact edge Hr for the rail and the height of the contact edge Hs for the carriage (shown in the images). Both are important dimensions to ensure a form-fit connection on the carriage and rail. In addition to the contact edges Hr and Hs, the values of the edge radii Ra1 and Ra2 are also important.





These illustrations show you the important dimensions for the connecting structure.

The specific assembly tolerances can be found in the manufacturer's catalogues, for example here. These depend on the respective manufacturer and are therefore individual. The above-mentioned contact surfaces must always be adhered to in accordance with the manufacturer's specifications in order to ensure homogeneous, smooth running, prevent impermissible deformation of the carriages and not reduce the service life. In addition, the straightness and evenness of the mounting surfaces is essential for many applications, such as machine tools, due to clear precision requirements.

Example of an assembly sequence

Suitable tools and aids must be used for the installation of linear guides. Certain instructions from the manufacturer must be observed: Screws of strength classes 10.9 or 12.9 must be used for the installation of linear guides. All screws must be tightened to the specified torque. Before starting assembly, preservatives must be removed from the mounting surfaces and linear guides. Temperature differences between the components to be assembled must be avoided. In order to protect against corrosion, it is recommended that clean gloves are worn – a direct contact with the linear guide should be avoided due to the transfer of salts through sweaty hands. Last but not least, components should only be removed from the packaging at the assembly site to prevent possible contamination of the components. The assembly area must also be free of dust and dirt, as the smallest particles in the μ range can cause significant damage to the linear guide if they get into the interior of the carriages. Assembly takes place in the order listed:

Assembly instructions 1) Preparation and cleaning of the mounting surface 2) Aligning the main rail 3) Pre-assembly of the rail 4) Positioning the rail (tightening the guide screws) 5) Fastening the rail (tightening the fastening screws) 6) Fastening further rails (steps 1 to 5 are repeated) 7) Assembly of the table 8) Completion of assembly (check of running behaviour to detect assembly errors before commissioning) More information can be found in the catalogue in chapter 3.5.

In addition to the instructions in the catalogue, NTN offers training and installation support for linear guide systems.

The type of mounting depends on the configuration of the linear guide. In this practical example, a linear guide with only one contact edge and no pressure screws is assumed. In such a case, four steps must be observed.

Practical example: Exemplary

1) The rail is pressed against the contact edge by hand and screwed tight. Tightening begins in the center of the rail and goes screw by screw to both rail ends. It must first be ensured that the contact edge and the contact surfaces are free of dust and dirt. 2) The second rail is then fitted; this is tightened slightly. 3) The table is positioned on the carriages and screwed in place. 4) The table is now moved along its entire length and the second rail is aligned with the first and screwed in place at the same time. The highest precision and accuracy must be ensured here in order to guarantee homogeneous running behaviour of the carriages on the rail.

In practice, installation is relatively straightforward in many cases.

Now you are well prepared for the installation of linear guides. If you would also like to find out more about the calculation principles for these products, click here.

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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.

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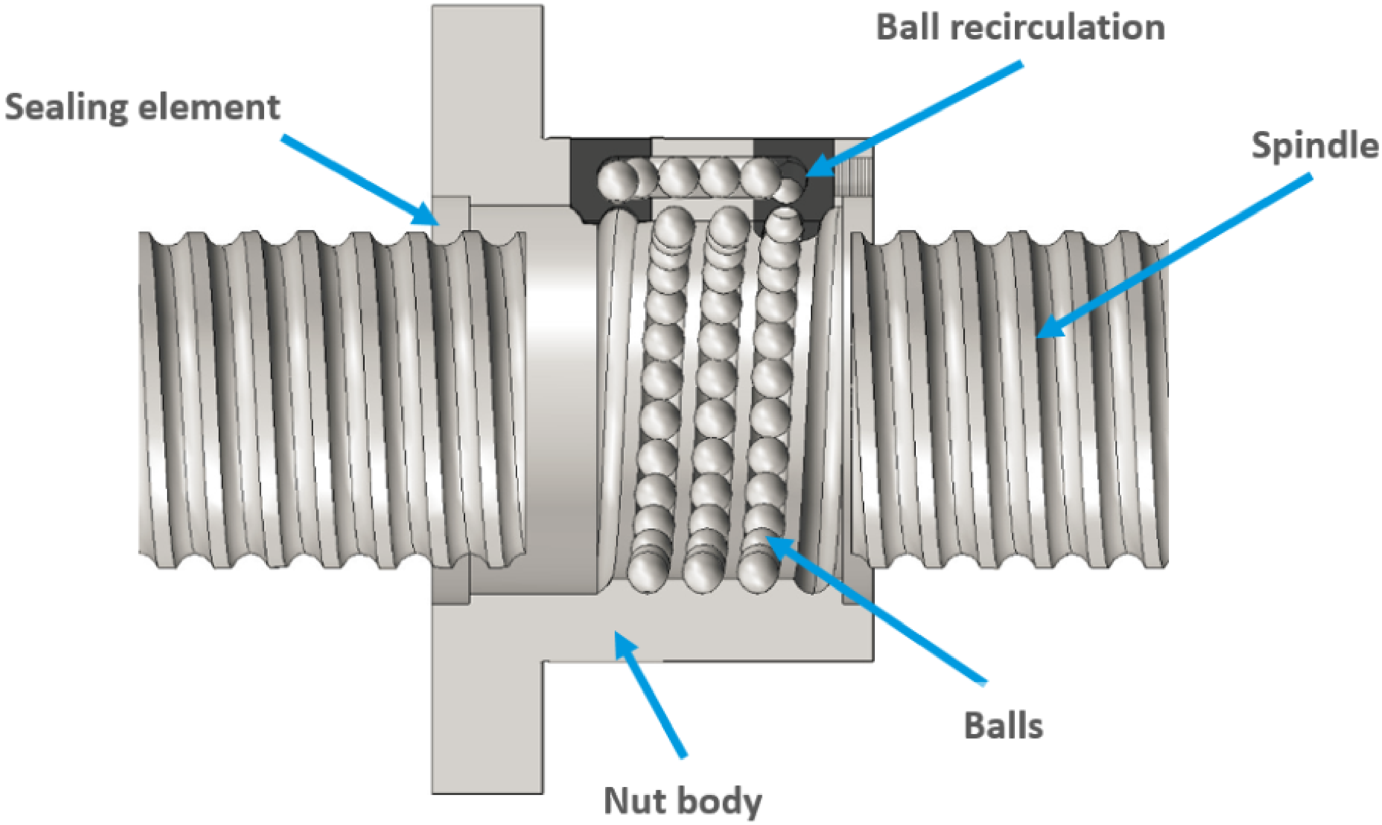
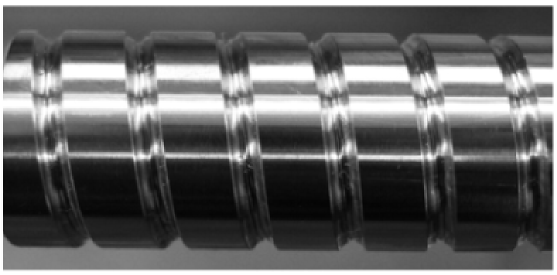
Design, mode of operation and areas of application of ball screws

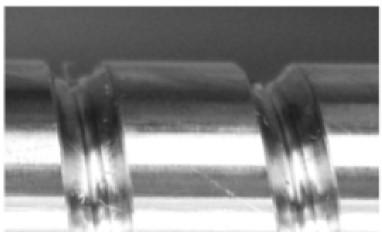
But first of all, what are ball screws? Ball screws consist of a spindle with a thread profile, a nut, which also has a thread profile inside and moves on the threaded spindle, and balls as rolling elements between the spindle and the nut. The use of seals is possible as an option. Ball screws are available in rolled, whirled and ground versions (more information on the three manufacturing processes can be found here).
Thread rolling has process-related limits in terms of achievable precision. The highest accuracy and precision requirements can be achieved by grounding, but grounding is the most expensive and takes the longest. In practice, thread whirling of ball screws is an effective and cost-effective alternative to ground variants, which can also achieve very high accuracy classes.
Ball screw drives are generally used to convert a rotary movement into a longitudinal movement. However, conversion in the other direction is just as possible, so that the nut is caused to rotate when an axial force is applied to the spindle. Ball screws can also be designed without axial clearance or preloaded.
Particularly important: Ball screw drives are only capable of absorbing axial loads and must never be subjected to radial loads or moments. Radial loads or moments will cause the ball screw to fail within a very short time! Vibrations, shocks and short-stroke applications should be avoided or at least minimized when using ball screws. In these cases, dimensioning with sufficiently high static safety is necessary. In addition, the correct preload class and an adequate lubricant should be selected – the manufacturer's recommendations in this regard should be followed at all times. Preload can be used to increase rigidity or achieve precision; it also serves to keep the balls in rolling contact in the case of vibrations, for example.
The areas of application for ball screws are comparable to those of linear guides and linear axis and are therefore similarly diverse, including the machine tool sector, medical technology, aviation, the food and packaging industry, semiconductors and photovoltaics. Ball screw drives are also used in glass molding machines and measuring machines.



The balls roll on the threaded raceway.

rolled





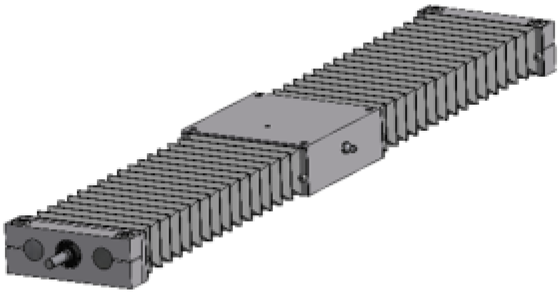
grinded

whirled

Visually there are differences between rolled and whirled or ground ball screw drives recognizable.

Trapezoidal screw drives as the forerunner of ball screws

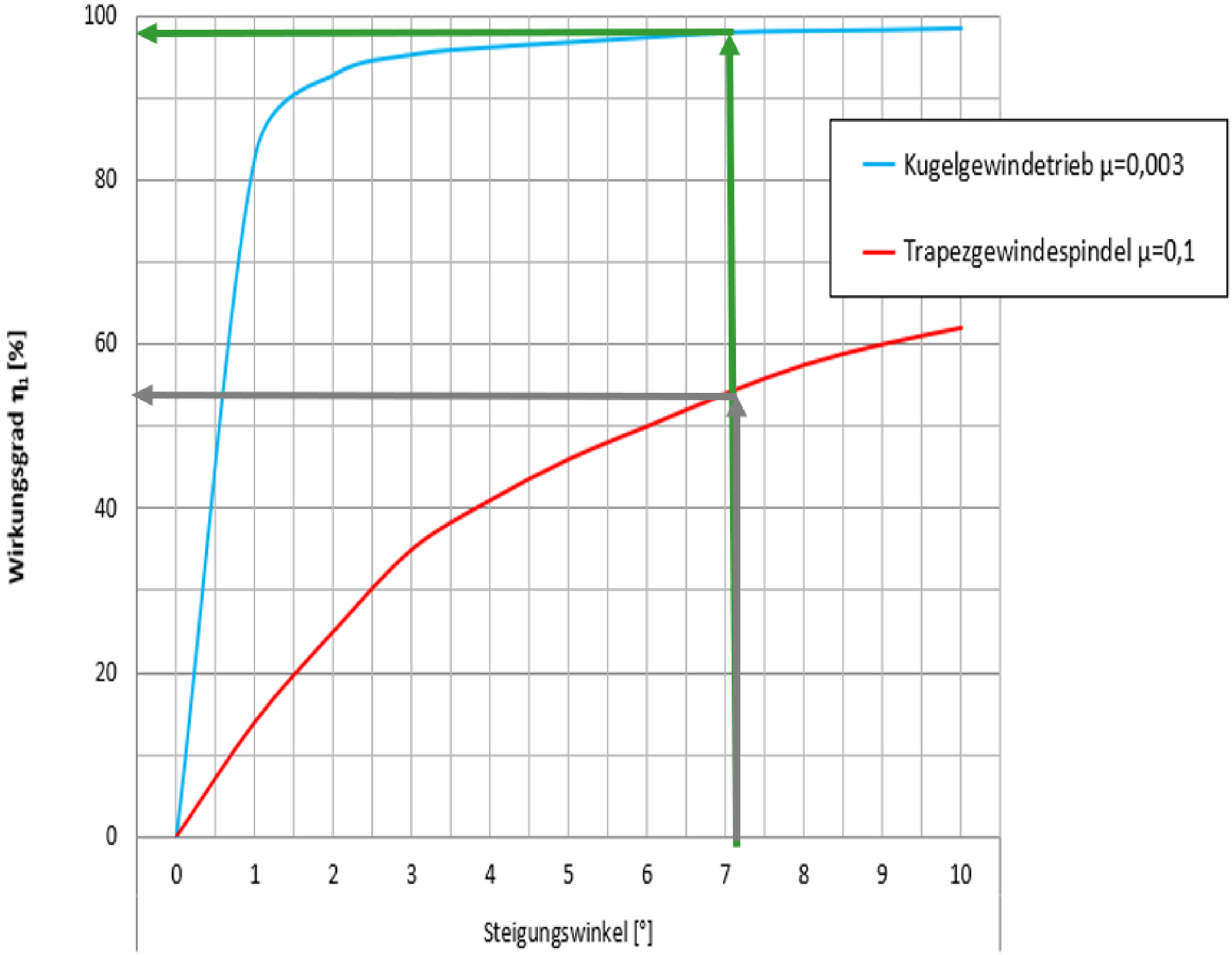
Trapezoidal screws have been on the market for much longer than ball screws and are used far less frequently than the latter. Their design differs from that of ball screws in that they have flat running surfaces and no rolling elements. Instead, they realize a sliding movement between two surfaces with a trapezoidal profile. This sliding motion causes friction, which leads to a comparatively shorter service life. Trapezoidal screw drives are also characterized by the fact that they must always have clearance, because if a trapezoidal screw drive is designed without clearance, it will jam. Due to the self-locking properties of trapezoidal screws, they are suitable for vertical applications with drives without brakes. They are also very suitable for applications that are mainly statically loaded or do not require much movement.



In this picture you can see a ball bushing table.

Ball screws and trapezoidal screws in comparison

As already mentioned in the previous section, ball screw drives are more important in everyday practice than trapezoidal screw drives. This is not only due to their generally more modern design and – because of the balls – low-friction, almost wear-free running. Due to this low-friction running, the decisive advantage is that ball screw drives are considerably more efficient.



This diagram can be used to determine the efficiency levels discussed above.

If, for example, a BSH02510 ball screw is compared with a TR02410 trapezoidal screw (both with a pitch angle of 7.1°), it is noticeable that the coefficient of friction for the trapezoidal screw is 0.1 µ. The coefficient of friction of the ball screw is generally only 0.003 µ. Taking the lead angle of 7.1° as an example, this means that the efficiency of the trapezoidal screw is around 55 %, whereas it is 98 % for the ball screw. Due to the relatively high friction, just under half of the energy applied is transformed into heat in the former, whereas almost all of the energy can be converted into active power in the ball screw.

In addition to efficiency, there are other advantages that ball and trapezoidal screw drives have in direct comparison with the other type of screw drive. All information on this is given in the table.

	Advantages
Ball screws	• Higher efficiency • Longer service life due to virtually wear-free operation • Lower drive power • No stick-slip effect • More precise positioning • Higher travelling speed • Less heat
Trapezoidal screw drives	• Self-locking (relevant for vertical applications with drive without brake) • more cost-effective solution

In most applications, ball screws are the better choice than trapezoidal screws.
You can also find more information on the calculation principles and the installation of screw drives on this website.

Configurator for ball screws

NTN provides a new online tool that generates ball screw type codes to efficiently select the right product. Following a step-by-step selection of all possible options, the tool configures the correct type code. In addition, products from other manufacturers can be interchanged by entering the brand, nut type, nominal diameter or pitch. Alternatively, this is also possible simply by entering the type code of the competitor's product. A login is not required, the configurator can be used directly.

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Calculation principles (screw drives)

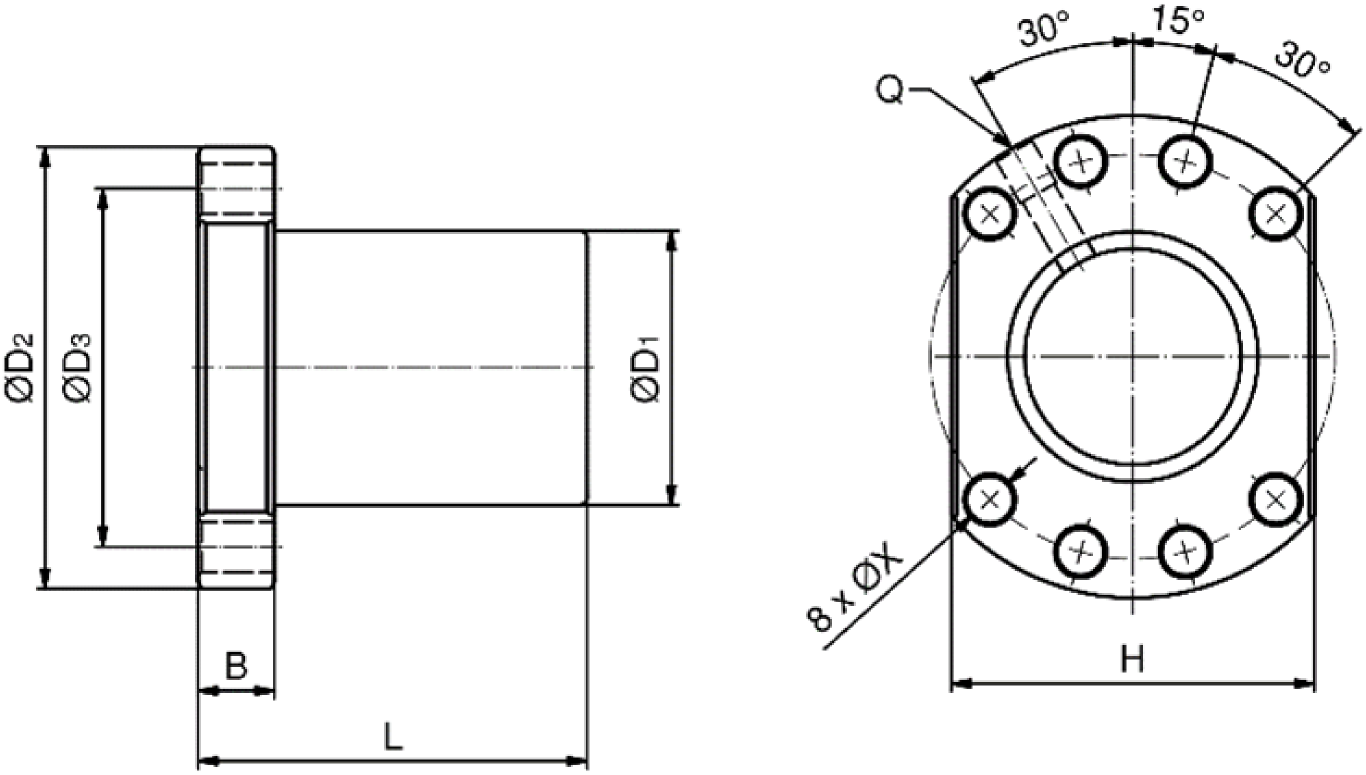
The calculation bases for screw drives are extensive and range from the calculation of the static safety factor to the critical speed, the buckling load and the nominal service life. All of this awaits you below. If you are looking for further calculation bases, you will find them in our catalogue.

Definition of screw drives

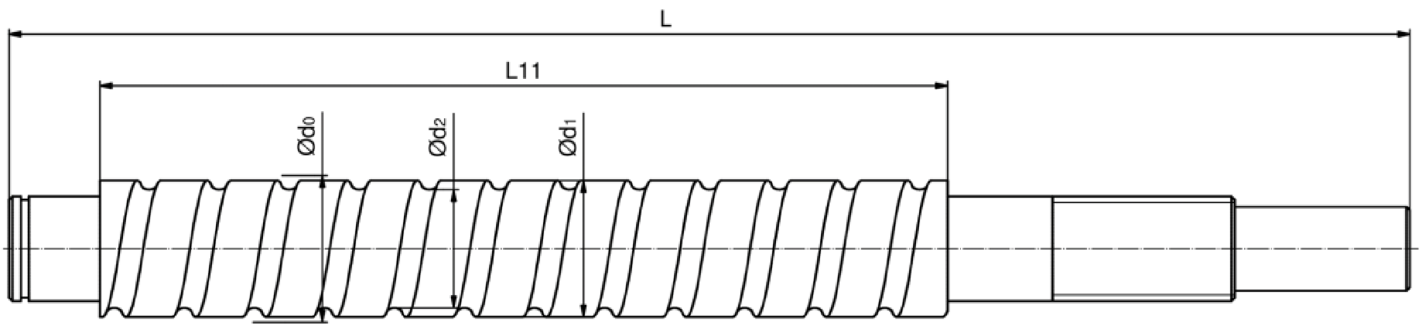
From a mathematical point of view, several factors must be taken into account when defining screw drives. Screw drives have a nominal diameter d_0, which is a round value and cannot be measured directly for every product. What can be measured, however, is the outer diameter of the screw d_1, which in many cases – but not always – deviates from d_0. The spindle core diameter d_2 and the ball centre-to-centre diameter D_{pw} are used to calculate certain dynamic parameters. The latter diameter is measured from the center of the ball on one side to the center of the ball on the other side. The pitch P is also of essential importance, while the use of the pitch angle β is rarely necessary.
There are three main values to consider for the nut: the outer diameter of the nut body D_1, the flange diameter D_2 and the pitch circle diameter of the flange D_3. Further parameters are the nominal ball diameter D_w, the static axial load rating C_{0a} and the dynamic axial load rating C_a. The nut length must also be taken into account.

Ball screw drive $\varnothing d_0$ = Nominal diameter $\varnothing d_1$ = Outer spindle diameter $\varnothing d_2$ = Spindle core diameter $\varnothing D_{pw}$ = Ball centre-to-centre diameter P = Pitch β = Pitch angle	Mother $\varnothing D_1$ = Outer diameter of the nut body $\varnothing D_2$ = Flange diameter $\varnothing D_3$ = Pitch circle diameter of the flange Ball $\varnothing D_w$ = Nominal diameter of the ball C_{0a} = Static axial load rating C_a = Dynamic axial load rating

In this overview you will find all the mathematical definition criteria for ball screws, nuts and balls at a glance.



You can use these measurement sheets to check the values D_1 , D_2, D_3...



...as well as d_0 , d_1 and d_2.

Calculation of the drive torque

The efficiency is the percentage of the applied energy that is converted into active power. The formulas and parameters required for this are as follows.

Formula 4: Calculation of the drive torque T $$T = \frac{F_a \times P}{2 \times \pi \times \eta}$$		Formula 5: Calculation of the axial force F_a $$F_a = m \times a \times \mu$$	
T	Drive torque	m	Mass
F_a	Axial force	a	Acceleration

P	Pitch	μ	Coefficient of friction of the drive system
η	Efficiency from conversion from rotation into linear movement		

Both the efficiency η and the axial force F_a are important for determining the drive torque T.

Load ratings: the axial static load rating C_{0a} and axial dynamic load rating C_a

The axial static load rating C_{0a} describes the constant axial load that generates a total plastic deformation of 0.00001 times the ball diameter. According to DIN, the axial load ratings – both axial static and axial dynamic – based on tolerance class 5. The axial static load rating C_{0a} is calculated on the basis of DIN 69051-4.
The calculation of the axial static load rating C_{0a} is also relevant in addition to the calculation of the axial dynamic load rating C_a. The axial dynamic load rating C_a is defined as the axial load that is unchanging in size and direction and under which a ball screw drive theoretically achieves a service life of 10^6 revolutions. The axial dynamic load rating C_a for ball screws is also determined in accordance with DIN 69051-4.
With regard to the axial load ratings, it is important to note that the relevant information in the NTN catalogue refers to an optimum load distribution on all loaded balls for ball screws of tolerance class 5. For tolerance classes deviating from tolerance class 5, a correction factor f_{ac} must be taken into account, which can be read from the table.
The greater the pitch error of a screw, the less guarantee there is that all balls will bear equally. Consequently, if not all balls loaded evenly, the axial load rating decreases. It is therefore necessary to correct the axial load rating by taking the tolerance class into account.

	Tolerance class		
	0, 1, 3, 5	7	10
Correction factor f_{ac}	1.0	0.9	0.7

Correction factors for the different tolerance classes according to DIN ISO 3408-5 .

The static safety factor f_s

The static safety factor f_s must also be taken into account. This takes into account the fact that ball screw drives can be exposed to unforeseen loads. These can have various causes, such as vibrations, shocks or short start-stop cycles. The static safety factor f_s is used to prevent impermissible, permanent plastic deformation of both raceways and rolling elements of the ball screw. It is essential that this factor is appropriately observed to ensure the stability and functionality of the respective application with ball screws and to guarantee reliable operation under various load conditions. The static safety factor f_s must always be ≥ 1. If the assumed loads fluctuate greatly and tend to be unpredictable, a higher safety factor f_s should be used.
Although the calculation of the static safety factor for ball screws is not the same, it is similar to that for linear guides. For ball screws, the two influence factors (the hardness factor f_H and the temperature factor

f_T) are multiplied by the basic static load rating C_{0a} and divided by the maximum axial load F_{max}.
Formula 6

$$f_s = \frac{f_H \times f_T \times C_{0a}}{F_{\max}}$$

f_s	Static safety factor
f_H	Hardness factor
f_T	Temperature factor
C_{0a}	Axial static load rating [kN]
F_{max}	Maximum axial load [kN]

As with linear guides checking the static safety factor is also important for ball screw drives.
Even if there is no clear rule, there are certain guide values or recommendations as to how high this factor should be as a minimum. The factor depends on the movement speeds acting on the ball screw drive and how heavy the loads and how intense the vibrations and shocks are.

Operating conditions	Static safety factor f_s
• Slow movements • Low loads • No vibrations and shocks	1.0 ... 1.3
• Slow movements • Low loads • Light vibrations and shocks	1.2 ... 1.7
• Slow movements • Medium loads • Vibrations and shocks	1.5 ... 2.5
• Fast movements • High loads • Vibrations and shocks	2.0 ...4.0
• Fast movements • High loads • Strong vibrations and shocks	3.0 ... 8.0

Ideally, you need a low static safety factor f_s, but in extreme conditions or highly loaded applications this can (far) exceed 3.0.

The nominal service life L_{10}

The nominal service life L_{10} is the calculated service life that can be achieved with a 90 % probability of survival for ball screws under normal operating conditions. Several influencing factors are required to calculate the nominal service life of ball screws. These include the load factor f_w, the hardness factor f_H

and the temperature factor f_T. Furthermore, the axial dynamic load rating C_a and the average axial load F_m are required.

Formula 7	
$$L = \left(\frac{f_T \times f_H}{f_W} \times \frac{C_a}{F_m}\right)^3 \times 10^6$$	
L	Nominal service life [min^{-1}]
C_a	Axial dynamic load rating [kN]
f_w	Load factor
f_H	Hardness factor
f_T	Temperature factor
F_m	Average axial load [kN]

On linearwizard.com you will also find information on calculating the service life of [linear guides] *and* [ball bushings].

With regard to the load factor f_w, there are recommendations that depend on the operating conditions, more precisely on the strength of the vibrations and shocks that act on the screw drives in the individual application. If the conditions cannot be precisely predicted in advance, the load factor should be taken into account with a certain degree of certainty or based on experience with comparable applications.

Operating conditions	Speed [m/s]	Load factor f_w
No or very low vibrations and shocks	≤0.25	1.0 ... 1.2
Light 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	>2.0	2.0 ... 3.5
Short-stroke applications		3.5 ... 5.0

The load factor results from the operating conditions.

The nominal service life L_{10} can also be specified in units other than revolutions. Depending on the requirement, it can be specified in kilometers L_s, in hours L_h or in cycles $L_{\#}$.

Formula 8

Formel 12

$$L_s = \frac{L \times P}{10^6}$$		$$L_h = \frac{L}{n_m \times 60 \times ED}$$		$$L_{\#} = \frac{L \times P}{2 \times s}$$	
L	nominelle Lebens-dauer [min^{-1}]	L	nominelle Lebens-dauer [min^{-1}]	L	nominelle Lebensdauer [min^{-1}]
L_s	nominelle Lebens-dauer [km]	L_h	nominelle Lebens-dauer [h]	$L_{\#}$	nominelle Lebensdauer [Zyklen]

P	Spindelsteigung [mm]	n_m	Mittlere Betriebsdreh-zahl [min^{-1}]	*P*	Spindelsteigung [mm]
		ED	Einschaltdauer [%]	*s*	Verfahrweg

$$L_s = \frac{L \times P}{10^6}$$

L
Nominal service life [min^{-1}]
L_s
Nominal service life [km]
P
Pitch [mm]

$$L_h = \frac{L}{n_m \times 60 \times ED}$$

L
Nominal service life [min^{-1}]
L_h
Nominal service life [h]
n_m
Average operating speed [min^{-1}]
ED
Duty cycle [%]

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

L
Nominal service life [min^{-1}]
$L_\#$
Nominal service life [cycles]
P
Pitch [mm]
s
Stroke

Here you will find the formulas for converting the service life into kilometers, hours or cycles.

Further calculation principles can be found in NTN catalogue for ball screws. Information on mounting screw drives can be found in the corresponding article.

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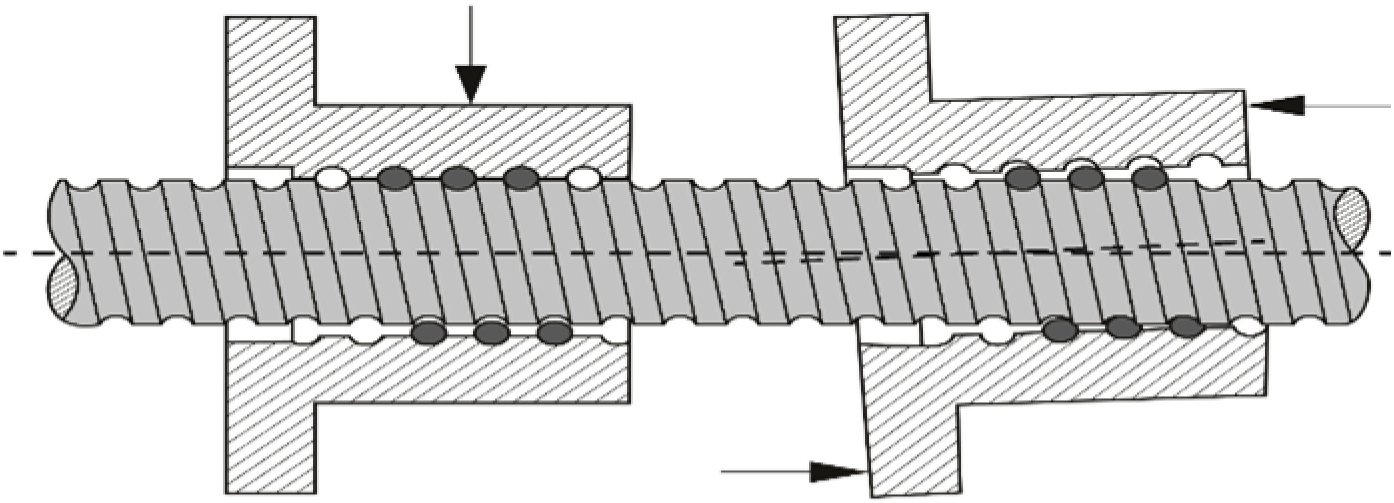
In the following article, you will learn everything you need to know about mounting screw drives. In addition to a general overview, you will find key information on the subject of assembly tolerances. You will find assembly instructions in the final part of this article.

General information

Before and during the installation of ball screws, you should be particularly aware of one thing: Ball screws are only suitable for the transmission of axial forces. Radial forces and moments, on the other hand, must not act on them under any circumstances. They represent undefined loads, for example due to tilted installation, and lead to premature failure of the product.



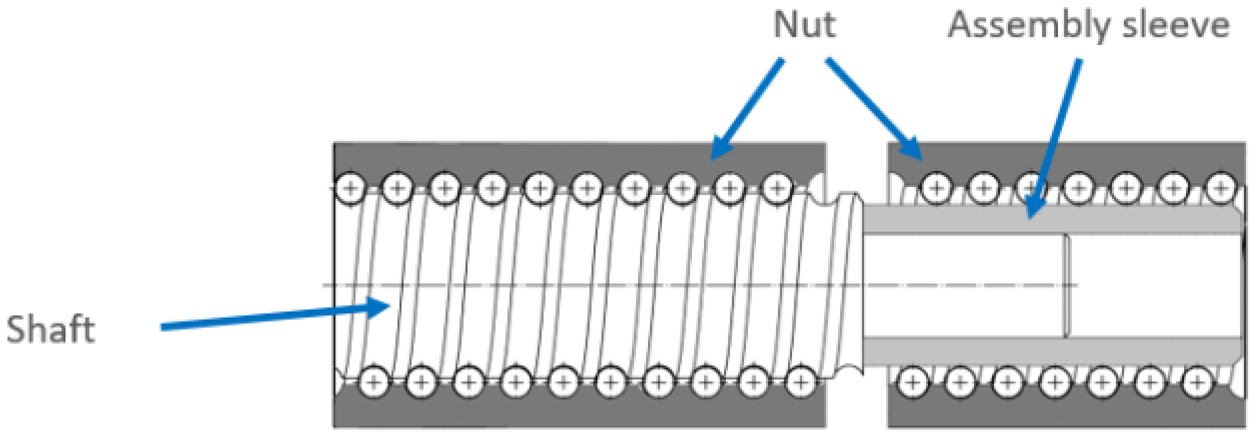
The following applies to ball screws: Radial forces are a no-go.

Assembly instructions

The assembly of ball screw drives is generally straightforward. The main assembly steps are listed below:

Assembly instructions for the nut
1) Remove the rubber ring on one side of the mounting surface or the cable tie. 2) Slide the nut with the mounting sleeve over the shaft end. 3) Press the sleeve against the start of the thread. 4) Turn the nut with slight axial pressure on the thread. 5) The entire length of the nut must be turned onto the spindle. 6) Do not remove the mounting sleeve until the nut is fully seated on the spindle thread. 7) Secure the nut against running off the spindle (with a rubber ring or axial locking of the sleeve). You can find more information on assembly here in chapter 3.

Although the assembly is relatively simple to carry out, typical sources of error should be pointed out. As separate ball screw nuts are supplied on mounting sleeves, the main error is to remove the mounting sleeve too early or to remove it incorrectly when the nut is hooked. The mounting sleeve must not be removed until the nut has been completely screwed onto the spindle. Otherwise, balls may be lost or enter the "dead gear". A "dead end" is a section of the thread profile of the nut that lies between two deflections and is not filled with balls. If balls get into the "dead end", they cannot circulate, which ultimately leads to the nut jamming.

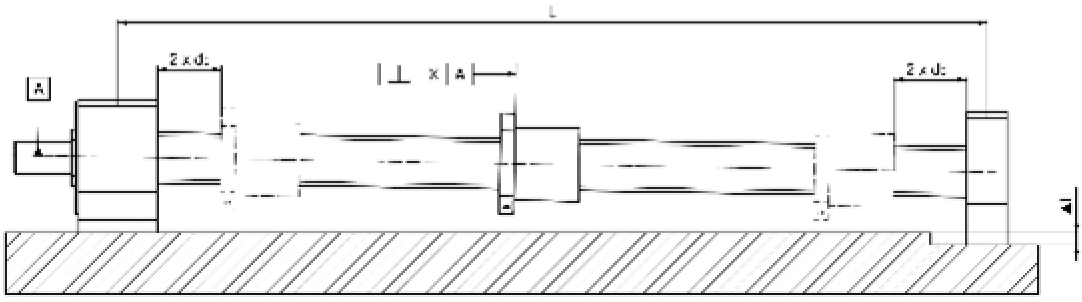


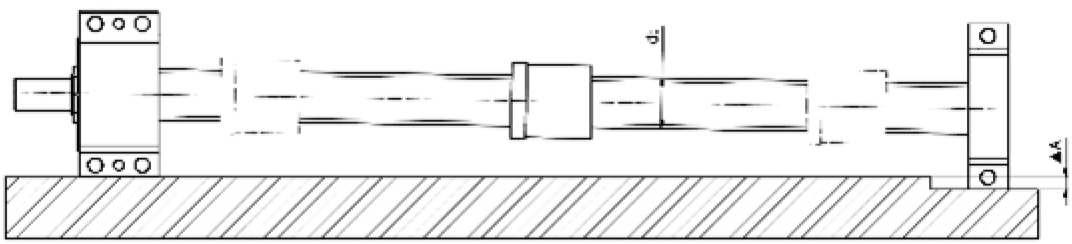
The nut is screwed onto the spindle using a mounting sleeve.

Suitable lifting equipment must be used when transporting and handling long ball screws. There should be several support points along the screw length to prevent the screw from sagging or deforming. In addition, all mounting surfaces of the connecting structure must be burr-free and clean. To prevent contact corrosion caused by hand perspiration, dry and clean gloves must always be worn during the assembly process.

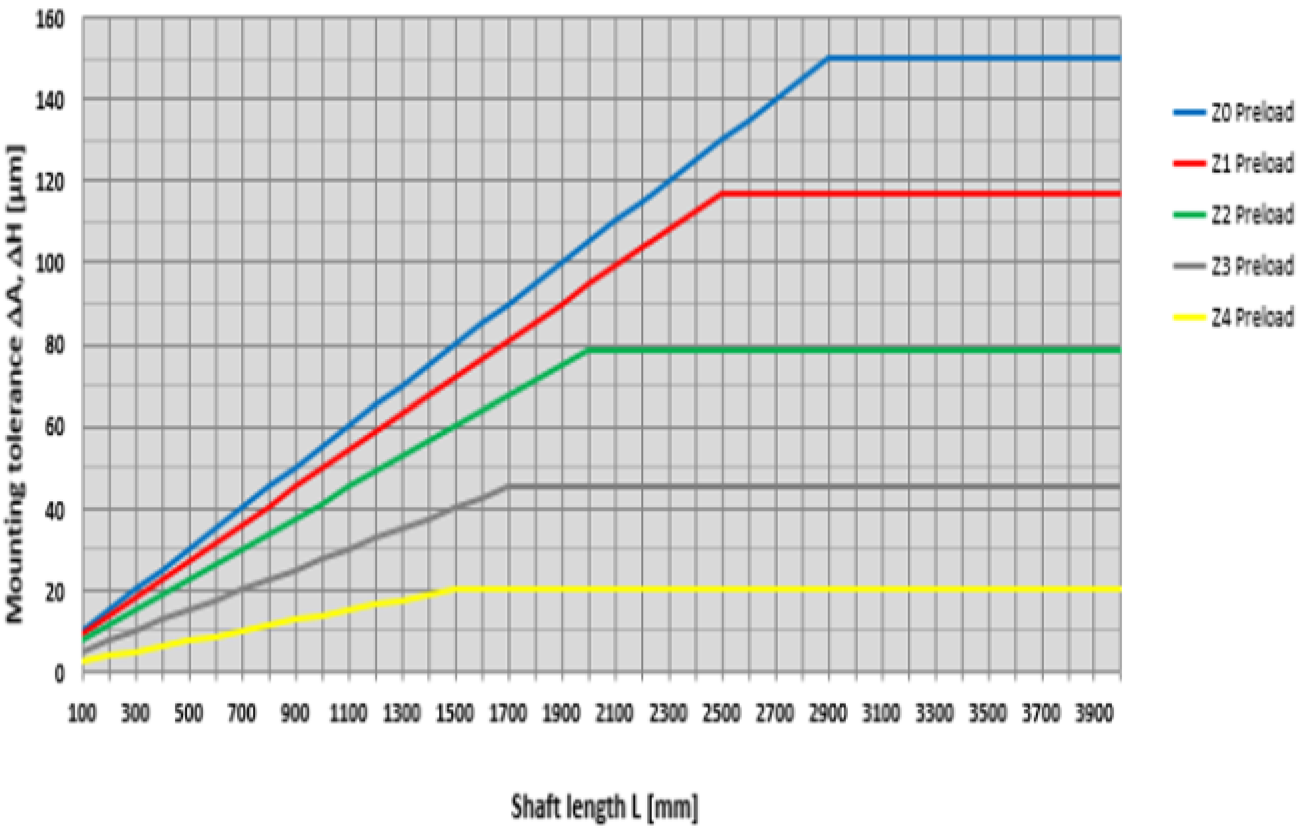
Assembly tolerances

Three directions must be taken into account for the assembly tolerances. These include the perpendicularity of the connecting structure to the spindle axis, the height offset ΔH of the bearings in relation to each other and the lateral offset ΔA of the bearings in relation to each other.





This dimension sheet shows the three directions that are relevant with regard to assembly tolerances.
On the one hand, the tolerance depends on the preload, because the more preload there is, the fewer tolerances are available. With increased preload, the frictional torque increases, and a higher drive power is required. Another factor is the length of the spindle. A diagram can then be used to determine how many µm of assembly tolerance must be maintained for each individual case, depending on the preload and spindle length.



This diagram shows the assembly tolerance taking into account the preload and spindle length.

Last but not least, the following instructions must be observed when installing ball screws.

The ball screw must be aligned parallel to the existing guides. The screw is precisely aligned if the torque is within the permissible limit values over the entire stroke after installation. In the event of any deviations, optimization is possible by subsequent alignment in the end positions. In this case, no attempt should be made to move the nut with increased force. Furthermore, it must be ensured that the permissible tightening torques are precisely adhered to and not exceeded for all screw connections. It should also be noted that nuts that are not initially greased must be sufficiently lubricated before the unit is moved for the first time.

In addition to general information on screw drives, you can also find out everything you need to know about their calculation principles at linearwizard.com.

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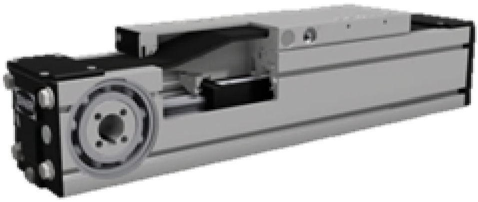
It should be emphasized that there is no uniform standard that defines the dimensions of linear axis and regulates the determination of their load ratings. With its SNR brand linear axis, NTN complies with the EU Machinery Directive and the associated standards. The linear axis presented below are SNR products, so it should be noted that the type designations listed are not transferable to other manufacturers.



Linear axis are available in countless shapes and sizes.

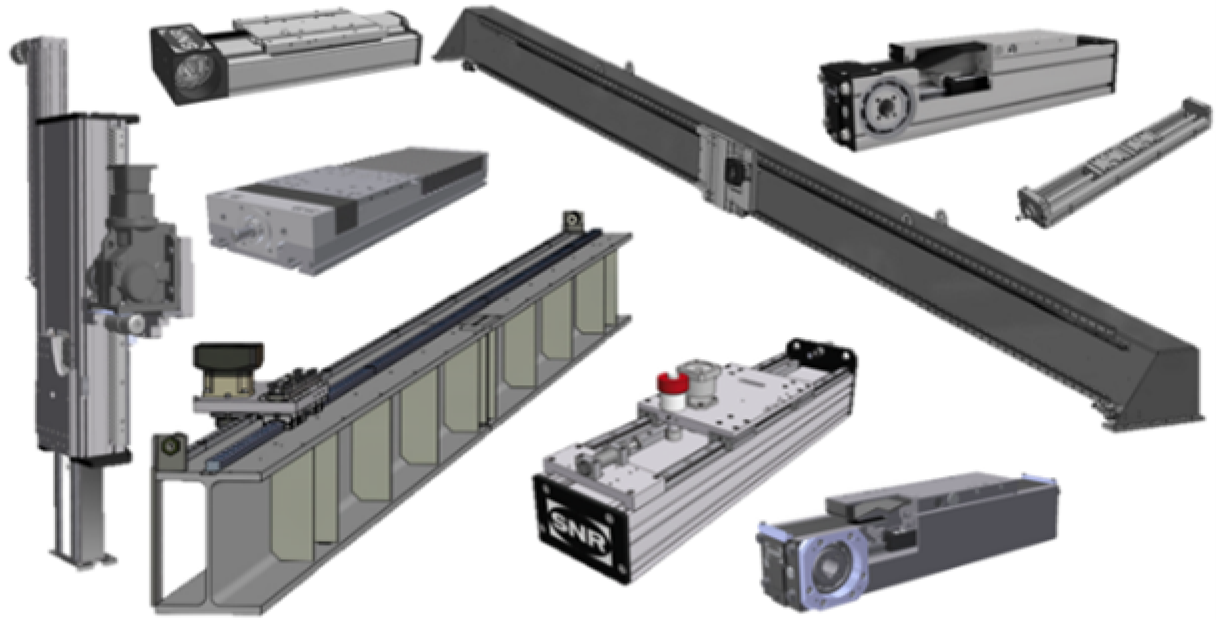
Areas of application

The areas of application for linear axis are diverse: they are used in battery cell production, in assembly systems in the automotive industry, in the handling of car and truck engines, in packaging machines, in the food industry and in robotic processes. Heavy-load axis can be found, for example, in the wood processing industry or assembly lines in engine production. In short, linear axis are just as suitable for simple handling tasks as they are for use in high-tech applications.

Customised linear axis

Unlike the standard version, customized linear axis are always adapted to the application-specific conditions and requirements. In concrete terms, this means that when designing a customized linear axis, all drive systems, i.e. toothed belt drive~~s~~ or toothed belt/□ drives, ball screw drives or trapezoidal spindles, rack and pinion drive~~s~~ and linear motor drives can be selected. It is also possible to use all guide systems, i.e. linear guides, track roller guides and polymer track roller guides. The customized linear axis are therefore characterized by their great flexibility.
Another flexible feature is that the travel range and configuration can be fully customized and selected with millimeter precision using the required attachments. Various equipment variants can also be configured for special environmental conditions. The product range of SNR linear axis makes it possible to handle masses ranging from a few grams to several tonnes. Customized linear axis are also service-friendly and low-maintenance. Relubrication is carried out via easily accessible grease nipples in the slider section. In combinations of gantry axis with lifting or telescopic axis, all lubrication points are often brought together via hose lines to a central and easily accessible point. In addition, the use of linear guides with ball chains enables long-term maintenance-free operation.

In contrast to the standard linear axis, the customized axis have a continuous base profile into which the drive and deflection elements are integrated, resulting in an optimum stroke-to-total length ratio. They are optimally sealed, depending on the type, for example by felt or lip wipers or a specially shaped cover strip. The use of side seals, bellows or cover plates is also possible as an option, depending on the type.



Because customized linear axis are designed according to individual requirements, there are significant differences in their appearance.

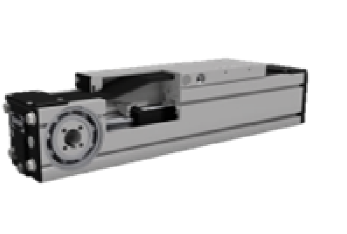
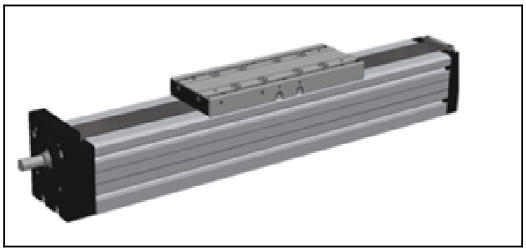
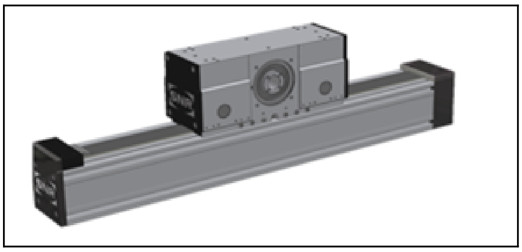
Customized linear axis are available in various series, including compact axis (AXC, AXF), parallel axis (AXDL), linear tables (AXLT), precision axis (AXBG), linear motor axis (AXLM) and heavy-load axis (AXS). The former and latter axis types are described in more detail in this article.

AXC linear axis

The AXC linear axis are compact axis based on lightweight, rigid aluminium profiles. A distinction can be made between five sizes, and there are also three different drive variants to choose from: toothed belt drive, toothed belt/□ drive and spindle drive. Either a linear guide or a track roller guide can be used a guiding system. As they are located inside the profile, all guide and drive components are very well protected.

The features and characteristics that can be attributed to each of the three drive variants of the AXC linear axis can be seen in the table.

Toothed belt drive AXC_Z	Spindle drive AXC_S/T	Toothed belt □ drive ACX_A
• High dynamics • Standard version with hollow shaft • Compact design with partially integrated planetary gearboxes possible • Connection of parallel axis via connecting shafts	• Equipped with ball screws without clearance or trapezoidal screw spindles • Different spindle pitches can be selected • Reinforced spindle bearing optionally possible • Deflection belt drive for limited installation space	• Well suited as a Z-axis for vertical movements of light and medium loads • High dynamics due to low moving mass • Belt and deflection pulley integrated in the drive head

Depending on the application, the use of a toothed belt, spindle or toothed belt/[illegible] drive is recommended.

AXS linear axis

There are four types of AXS heavy-load axis, including gantry axis, lifting axis, beam axis and telescopic axis.

	Gantry axis	Lifting axis	Beam axis	Telescopic axis
Base	Aluminium or steel profiles	Aluminium profiles (special version with steel profiles)	Aluminium or steel profiles	Aluminium profiles
Sizes	4	3	2	5
Drive variants	Toothed belt drive Rack and pinion drive	Rack and pinion drive	Rack and pinion drive	Toothed belt/[illegible] drive combined with toothed belt drive Rack and pinion drive combined with toothed belt drive
Guiding system	Two linear guides in parallel*	Two linear guides in parallel, different table lengths	one linear guide, different table lengths	Two linear guides in parallel, different table lengths
Suitable for	Highly rigid profiles for unsupported use over long distances	High dynamic operating forces Masses over 2,000 kg possible	Use of two parallel support axis with large distances including tables with tolerance compensation system	Limited space horizontal and vertical use High travelling speeds of up to 10 m/s
Features	Lengths up to 12 m (one-piece) Several independently slider units can be mounted on an axis with rack and pinion drive	Vertical handling in line and area portals Optional balance cylinder for very high loads and/or safety brakes possible	Lengths up to 12 m (one-piece) Several independently moving slider units can be mounted	Optional balance cylinder for very high loads and/or safety brakes possible

* Gantry axis can be designed with tabletops of different lengths or without tabletops for direct combination with lifting or telescopic axis.

Gantry and beam axis can reach lengths of up to twelve meters in one piece.

Customized solutions

There are numerous options for special linear axis solutions. For example, there are axis with several sliders (e.g. toothed belt axis with several slider units) that are connected to each other or driven independently. Another example of a special axis is a ball bushing table. In general, however, a special axis can also be manufactured individually according to customer requirements.

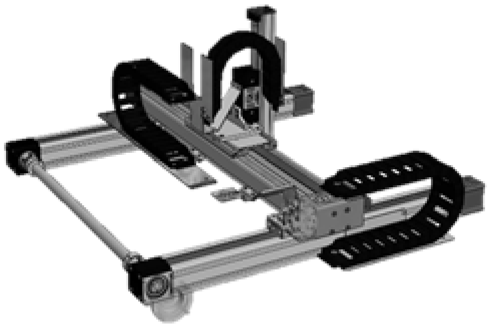
Standard linear axis (AXE)

The standard linear axis (AXE) have a toothed belt or toothed belt/□ drive and are considered easy to service and low-maintenance in the application. The latter means that relubrication is carried out using easily accessible grease nipples in the slider part of the linear axis. In addition, the use of ball chains enables long-term maintenance-free operation of the linear axis. The advantages of these standard linear axis are their internal guide components: The guides are accordingly protected from direct contamination on the inside, and the profile is also closed at the top by the toothed belt for smaller sizes and by cover strip for larger versions. They are also characterized by their modular design, which offers flexibility in terms of production and manufacturing locations and is therefore available to customers more quickly, as only standard components are used. AXE axes can be used horizontally as well as vertically.
Standard linear axis are available in several sizes (from 40 as the smallest up to 160 as the largest version), guide systems and, depending on the product, with cover strips.

Standard linear axis can be equipped with numerous standard accessories if required.
A wide range of accessories is available for standard linear axis. The accessories include – without listing all parts here – standard connecting elements such as sliding blocks or fastening strips, as well as one-stage planetary gearboxes, motor adapters, couplings, plug-in shafts and limit switches.

Standard axis systems

Standard axis systems are available in variants A and B, with variant B being the larger system. They can be selected as 3-axis or 2-axis systems (in the XY or YZ arrangements). A standard axis system includes all connecting elements, for example for connecting the linear axis to each other and for attaching the energy chains. In addition, all standard stroke lengths can be selected, and energy chains are also included as standard in the scope of delivery of a standard axis system. Only the selection of coupling cones and gearboxes has to be done separately.



Standard axis systems of variant A combine the linear axis AXE60Z, AXE110Z and AXE40A, those of variant B the linear axis AXE80Z, AXE160Z and AXE60A.

Configurator for linear axis

The NTN online configurators for standard linear axis are practical aid. Both AXE single axis and AXE axis systems can be configured. To generate a single axis, the tool requires the input of factors such as size, drive type and travel distance. In order to select an axis system, information is required on the travel ranges and table positions of the X, Y and Z axis, for example. The online configurators for AXE-single axis and AXE-axis systems can be found on the NTN website.

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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
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In this article, linear axis are categorized according to their drive variants, with toothed belt drives, spindle drives, rack and pinion drives and linear motor drives being the four relevant types. However, you should note that the differentiation can vary, which means that they can be categorized not only according to their drive variants, but also according to the other distinguishing features listed in the table.

Differentiation of linear according to:

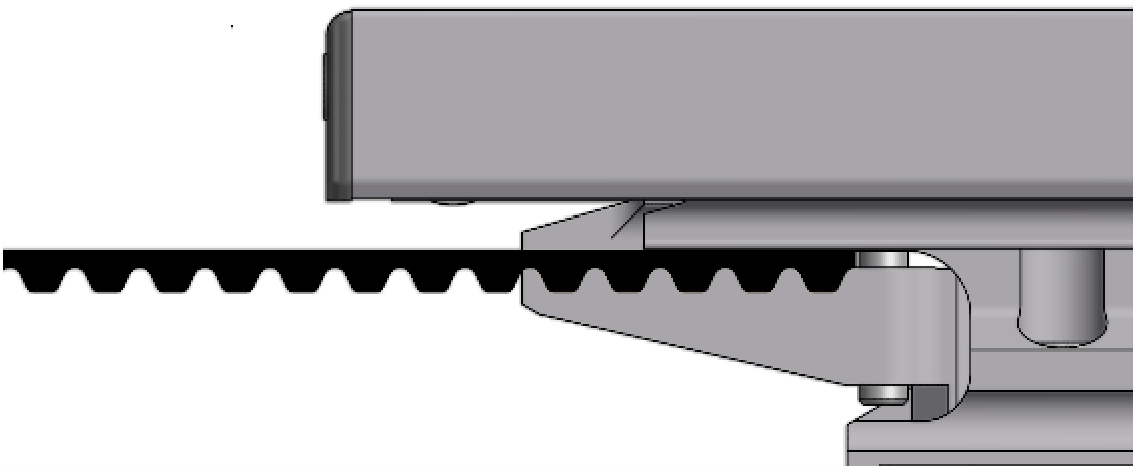
- Types of guide systems
- Internal or external guide systems
- Drive variants
- Base material
- Production of customized lengths or standard lengths

The differentiation by type of drive system is only one of five differentiation options for linear axis.
As it is not possible to make general statements about linear axis, the following section focuses on NTN linear axis of the SNR brand.

Toothed belt drives

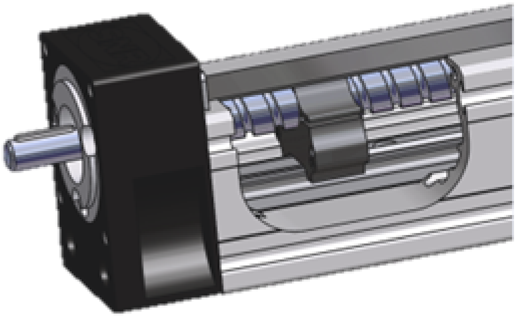
Linear axis with toothed belt drive are suitable for fulfilling fast handling and positioning tasks. All axis are equipped with an AT or STD toothed belt, whereby the toothed belt clamping via the toothed segment in the toothed belt width enables unweakened clamping. Thanks to a radially adjustable bearing of the deflection pulley, the toothed belt tension can also be set precisely using the SNR toothed belt tensioning device, which consists of a force gauge and adapter devices for the respective axis type.
The advantages of this method of tensioning the toothed belt:

- No risk of overloading the toothed belt during installation
- No premature failure of the pulley bearing due to excessive belt tension
- Optimum running properties thanks to centered alignment of the toothed belt during installation
- low wear



Toothed belt drives are characterized by low wear, among other things.

Spindle drives

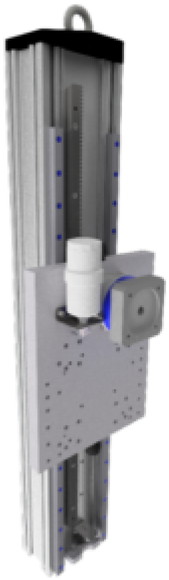


In this illustration you can clearly see the spindle, which is located in the linear axis.

Linear axis with screw drives are characterized by the fact that they can be equipped with ball screws or trapezoidal screws. They are particularly suitable when there are high requirements for positioning accuracy and repeatability in combination with high rigidity of the drive element. In addition, direct drive adaptation is possible via a coupling and coupling cone or with the aid of a deflection belt drive. Spindle drives can also be used to achieve high positioning accuracy over long travel distances. In applications that require longer travel distances and higher speeds, spindle drives can be equipped with spindle support units. In addition to the fact that relatively high speeds are possible, these spindle support units also serve to shorten the free length of the spindles – i.e. the distance between the nut and the floating bearing – by half or two thirds, for example, and thus increase the critical speed.

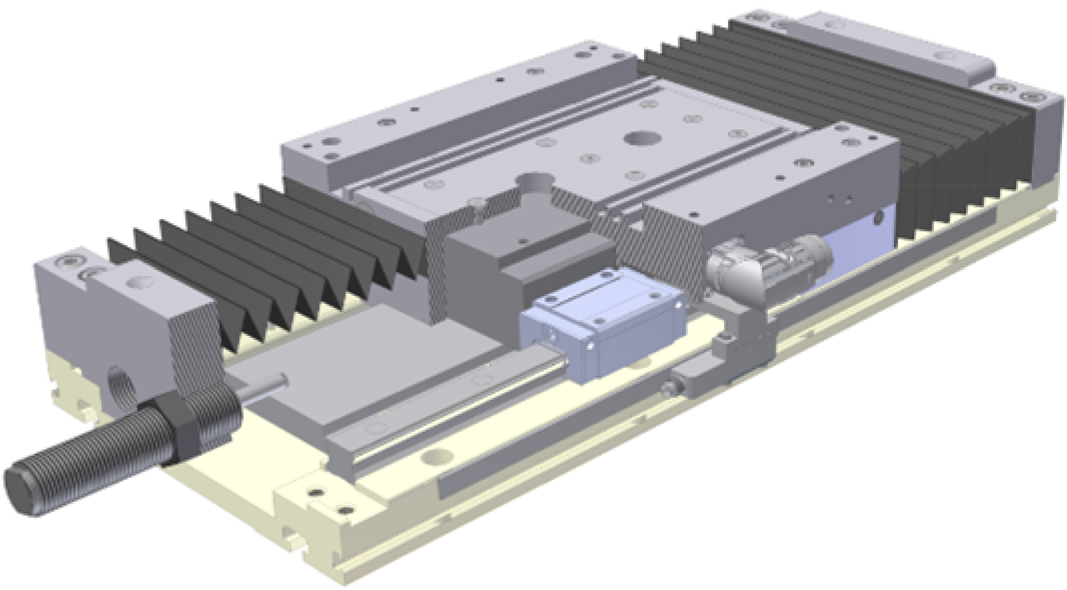
Rack and pinion drives

Rack and pinion drives are another drive variant of linear axis. These are characterized by high operational reliability and are therefore suitable for vertical applications. As the rack consists of rack segments, theoretically unlimited travel distances are possible, which means that linear axis of any length can be built. For this reason, rack and pinion drives are ideal for use in large gantry axis, for example. The induction-hardened racks and gear wheels of this drive variant guarantee a long service life; it should also be mentioned that rack and pinion drives – even with heavy loads – have the highest rigidity in the drive system.



The use of linear axis with rack and pinion drives is particularly suitable for vertical applications.

Linear motor drives



Linear motor drives can be used at very slow speeds without any problems; the same is also possible with rotary drives, but this requires gearboxes with extremely large ratios.

The use of linear motor drives is particularly suitable for applications where the highest demands are placed on positioning accuracy and repeatability. One major advantage is their flexibility, as they are suitable for both extremely slow (e.g. 1 cm per hour) and very fast movements. Linear motor drives are maintenance-free drive elements and can theoretically be used for unlimited travel distances. One disadvantage of linear motor drives is that they have no braking function in the power-off state, which can be critical in vertical applications.

Overview of the advantages and disadvantages of the drive systems

The following overview provides a direct comparison of the most important advantages and disadvantages of the drive systems mentioned above.

	Advantages	Disadvantages
Toothed belt drive	• High dynamics • Long lengths • Cost-effective • Maintenance-free	• Lower dynamic operating load • Lower drive stiffness • Normally a gearbox is necessary • Lower repeatability
Spindle drive	• High positioning accuracy and repeatability • High feeding forces • High drive rigidity • Usually, no gearbox necessary	• Speeds limited by critical speed and DN value • shorter maximum lengths • Relubrication necessary
Rack and pinion drive	• Theoretically unlimited lengths possible • Several independently travelling drive units possible • High feeding forces • Highest drive rigidity	• Relubrication necessary • Lower positioning accuracy and repeatability
Linear motor drive	• Very high positioning accuracy and repeatability • Very high dynamics • Wear-free and maintenance-free drive • Theoretically unlimited lengths possible	• No breaking of the system in the power-off state (vertical use critical) • Relatively high costs

It should always be made dependent on the respective application which drive variant is used.

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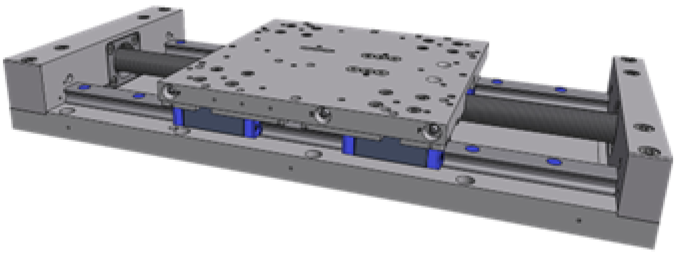
Three different types of guiding variants are used in the area linear axis, each of which is designed for specific applications. You can choose between linear guides, track roller guides and polymer track roller guides, each of which is adapted to specific application requirements. The parameters and requirements mentioned in this article refer to NTN linear axis of the SNR brand.

Linear guides

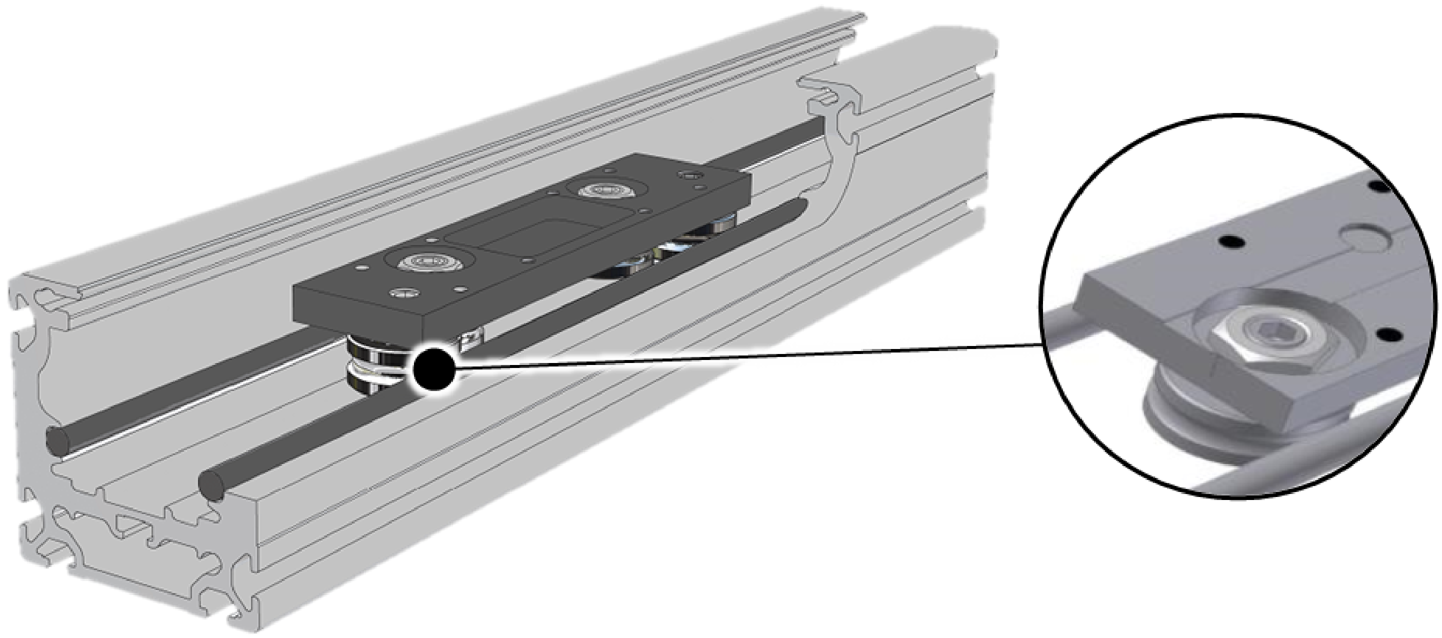
With regard to linear guides, it can be said that only carriages with an integrated ball chain are used. A linear guide with ball chains is also considered to require no long-term maintenance, offers optimum running behaviour and a very high tolerance compensation capacity, which is particularly important when using parallel axis. Linear guides are suitable for use at speeds of up to 5 meters per second. In general, they also have a low noise level compared to the conventional design.



As a rule, carriages with integrated ball chains are always used for linear guide systems; this principle is only deviated from in very rare special applications.

Track roller guides

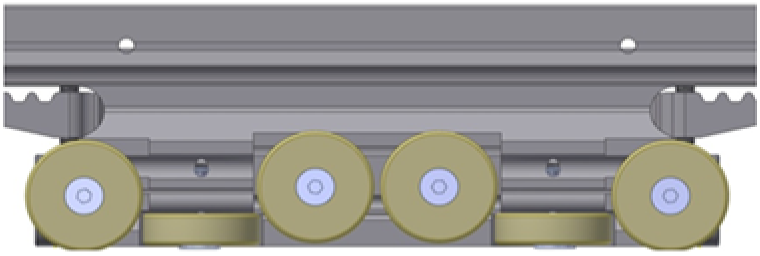
The track roller guides are a dust-protected roller system that is integrated into the aluminium profile of the linear axis. In this case, there are ground and hardened steel shafts that are pressed into the aluminium profile and serve as raceways. The rollers are double-row angular contact ball bearing with a profiled outer ring, which are suitable for maximum speeds of up to 15 meters per second. Each guiding system has four, six or eight rollers, half of which are adjustable via eccentrics in order to achieve a clearance-free system. The number of rollers depends on the size and type of linear axis.



A characteristic feature of track roller guides is the specially shaped aluminium profile that accommodates the ground steel shafts, which have the function of tracks.

Polymer track roller guides

The polymer-track roller guides are special versions designed for applications in the food industry or in wet areas. As these are plastic rollers, their raceways are located directly on the inner surfaces of the aluminium profile. In addition, the clearance-free system in this type is achieved by a spring element integrated into the two-part slider unit. Polymer track roller guides are suitable for applications where speeds of no more than 7 m/s occur. The guiding system always consists of twelve track rollers in order to be able to absorb forces in all directions.



The polymer track roller guides are used in particularly sensitive areas of application, for example in the food sector.

A comparison of the three guiding systems

As already mentioned in the previous paragraphs, all guiding systems naturally have their advantages and disadvantages. The most important aspects are listed again in detail and in direct comparison in the table.

	Advantages	Disadvantages
Linear guide	• Very high load capacity • High rigidity • High tolerance compensation capacity	• Higher costs • Maximum speed of 5 m/s
Track roller guide	• Very cost-effective, especially for large strokes • Maximum speed of 15 m/s	• Low load capacity
Polymer track roller guide	• Very suitable for use in wet areas • Maximum speed of 7 m/s	• Very low load-bearing capacity

Track roller guides can be used at 15 m/s at the comparatively highest maximum speeds.

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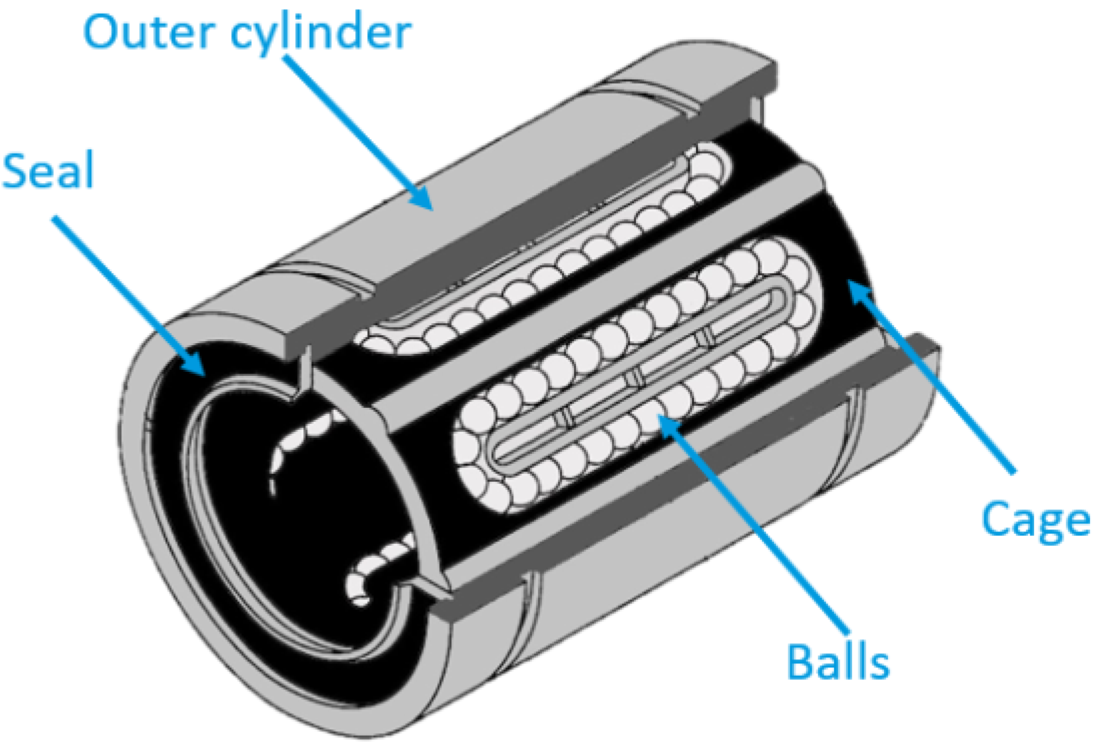
History

Ball bushings are considered to be the oldest product with rolling element recirculation in the field of linear motion and therefore the first to be categorised under the term "linear guide". The beginnings of ball bushings can be traced back to the First World War. At that time, they were developed to move the flaps of the tail units of US military aircraft, which ran on wire ropes. However, the first ball bushings as we know them today were not developed until a few decades later, in the 1940s. Nowadays, ball bushings are standardised in accordance with DIN ISO 10285 and DIN ISO 14728.

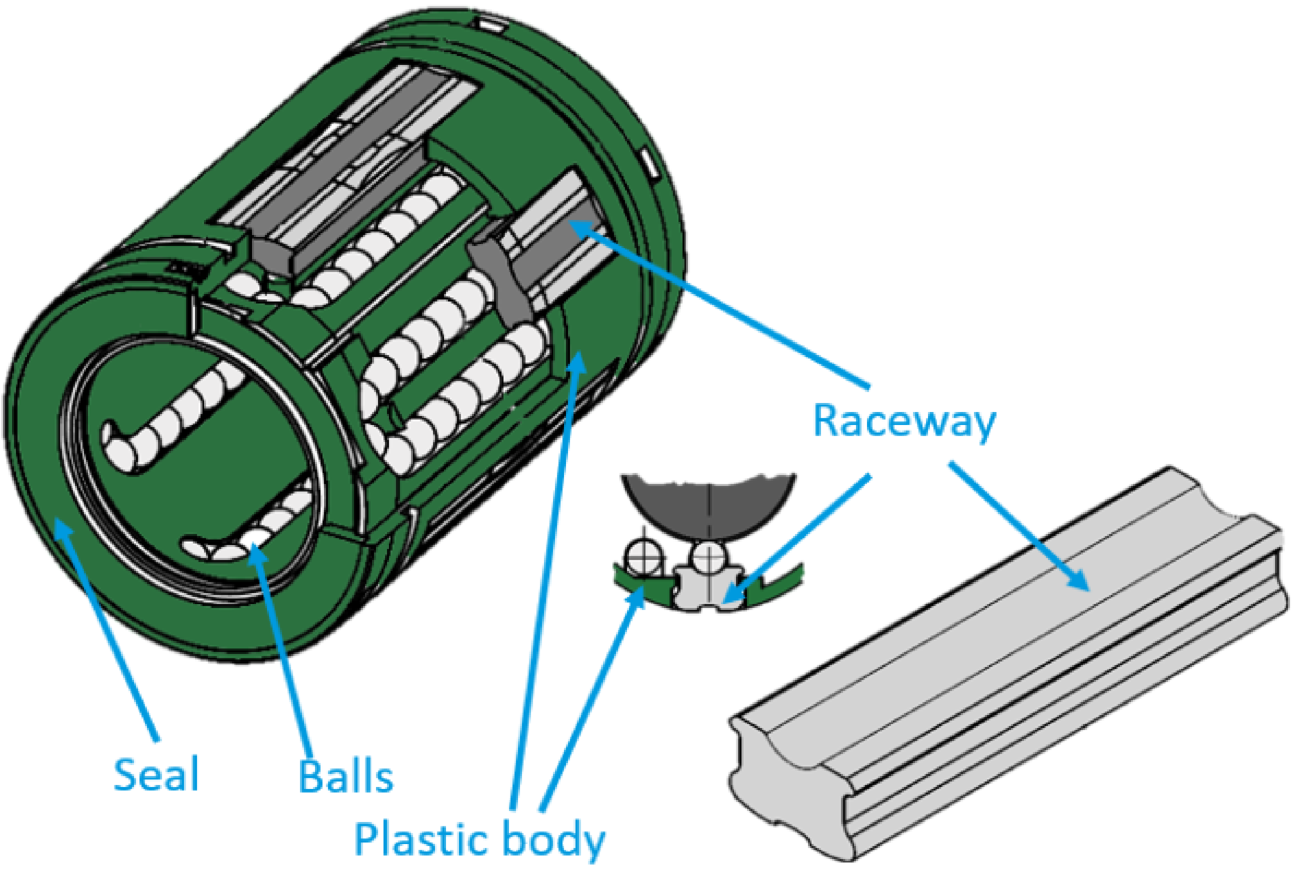
Features and structure

There are two basic types of ball bushings: Standard and super ball bushings.
Standard ball bushings consist of a metal outer cylinder, balls as rolling elements, which are guided by a cage, and optional seals.



The cage of standard ball bushings is made of either plastic or metal.

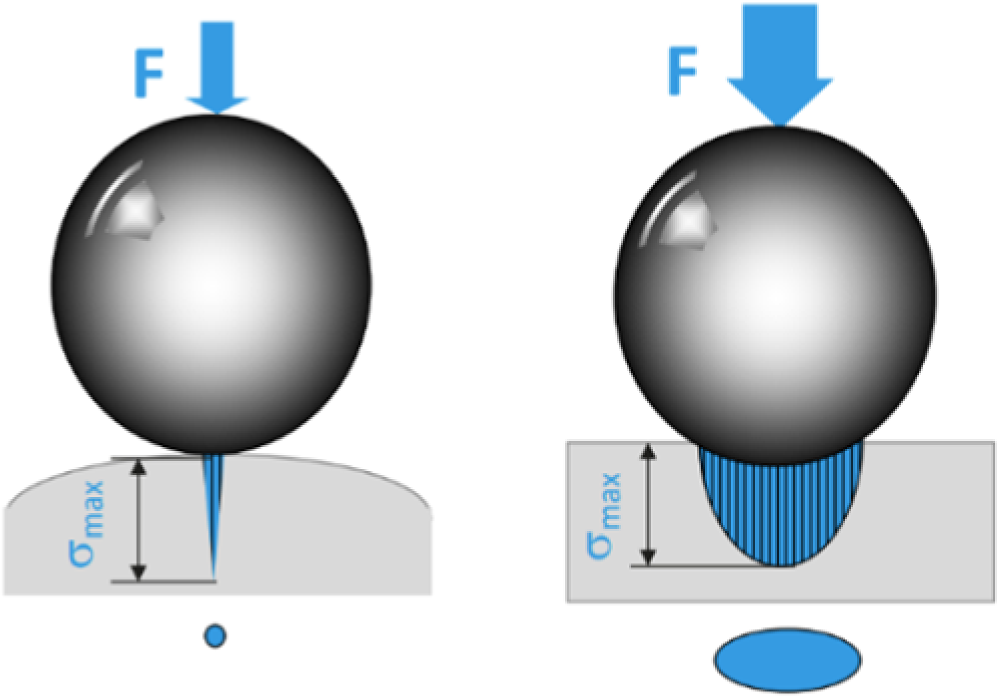
The design of the super ball bushings is generally similar to that of the standard version; their rolling elements are also balls and seals can also be used here if necessary. Unlike standard ball bushings, however, they have a plastic body into which the raceways, which are made of steel, are inserted.



You should note that different names are used for super ball bushings, depending on the manufacturer.

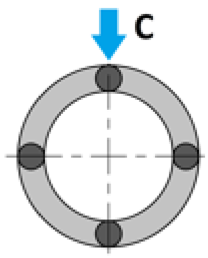
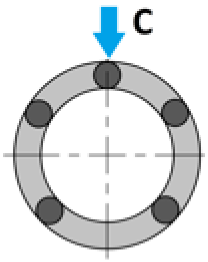
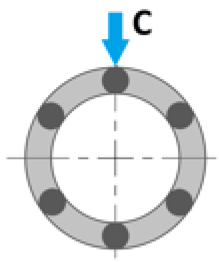
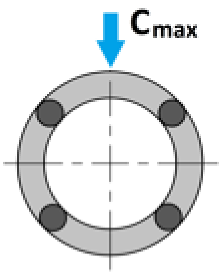
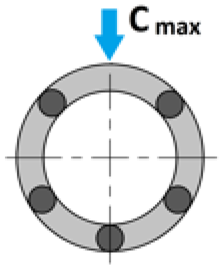
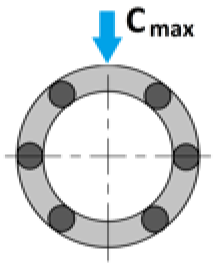
Load capacity

Compared to linear guides and ball splines, ball bushings have a significantly lower load-capacity. The rolling elements run on a shaft and have minimal point contact with the shaft, which is why it is not possible for ball bushings to support relatively heavy loads. More information on the topic of load ratings can be found here at linearwizard.com.



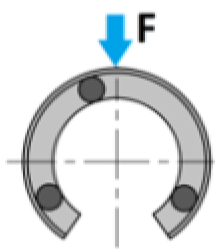
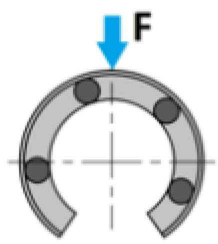
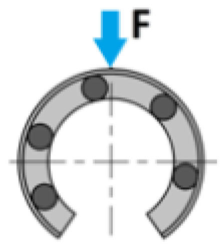
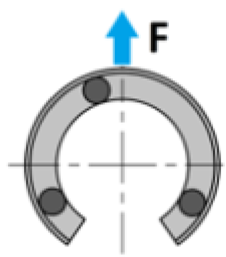
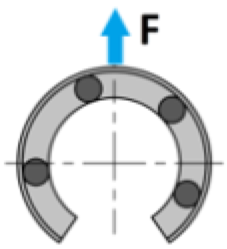
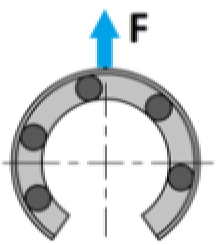
The contact surface is relatively small for point contact (left). The illustration on the right shows a surface contact of a linear guide for comparison.

The load-capacity of ball bushings varies depending on the arrangement of the raceways and the number of circuits. The following applies: the more circuits and the larger the diameter of the ball bushing, the higher the load capacity. With regard to closed and adjustable ball bushings, the term “directional” or “non-directional installation” is used, depending on how the force is applied to the row of rolling elements. If a ball bushing is installed in a directional manner, the ball circuits are aligned in such a way that the force is optimally distributed over the circuits so that the maximum load capacity can be achieved; at the same time, the nominal service life is increased. The load ratings from the data tables increase by a factor that is specified in the catalogue depending on the number of ball circuits. In the case of non-directional installation, the position of the ball circuits is not considered during assembly. The load ratings specified in the data tables are the minimum values that apply to the most unfavourable position of the ball circuits for non-directional installation.

Number of ball rows	4	5	6
C (catalog value)			
C_{max} (maximum load capacity)			
Load coefficient C_{max}/C	1,414	1,463	1,280

The catalogue value refers to non-directional installation, the maximum load rating C_{max} refers to directional installation.

Directional or non-directional installation is not possible with open ball bushings. A distinction is made here between the load in radial and in reverse radial. If the balls are loaded in the tensile direction, the load rating is ultimately lower, as the ball bushings tend to bend upwards.

Number of ball rows	3	4	5
Radial load	 C_{max} $C0_{max}$	 C_{max} $C0_{max}$	 C_{max} $C0_{max}$
Reverse radial load	 $C=0{,}64C_{max}$ $C0=0{,}64C0_{max}$	 $C=0{,}54C_{max}$ $C0=0{,}54C0_{max}$	 $C=0{,}57C_{max}$ $C0=0{,}57C0_{max}$

The illustration shows the application of force in the direction of radial (top) and in the direction of reverse radial (bottom).

Lubricant requirement

Due to the point contact, ball bushings require little lubricant. Although they do lose grease during operation, this is not a decisive factor in practice as it is only a small amount and ball bushings are not used in highly dynamic applications. Due to this low lubricant requirement, ball bushings are maintenance-free in many applications after initial greasing. It is the exception rather than the rule that ball bushings have a lubrication hole in the outer body for relubrication. In addition, the lubricant requirement naturally depends on the individual application.

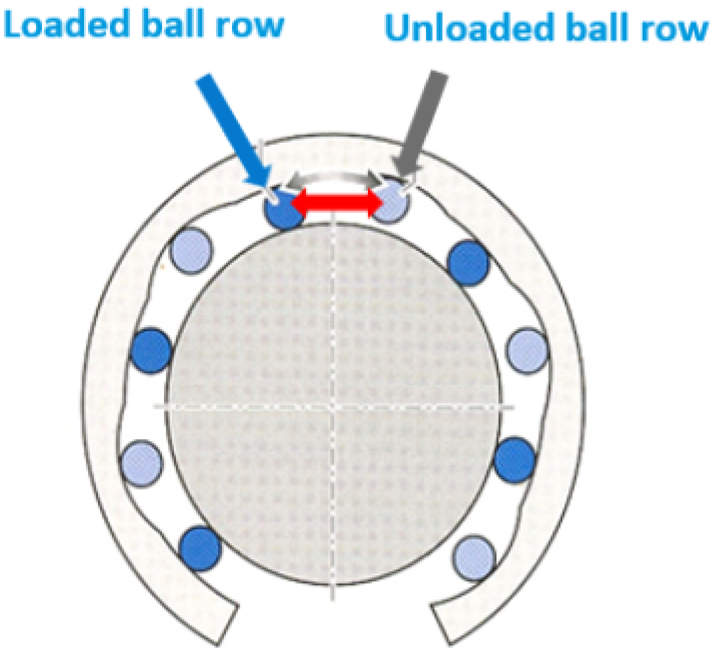
Friction coefficient

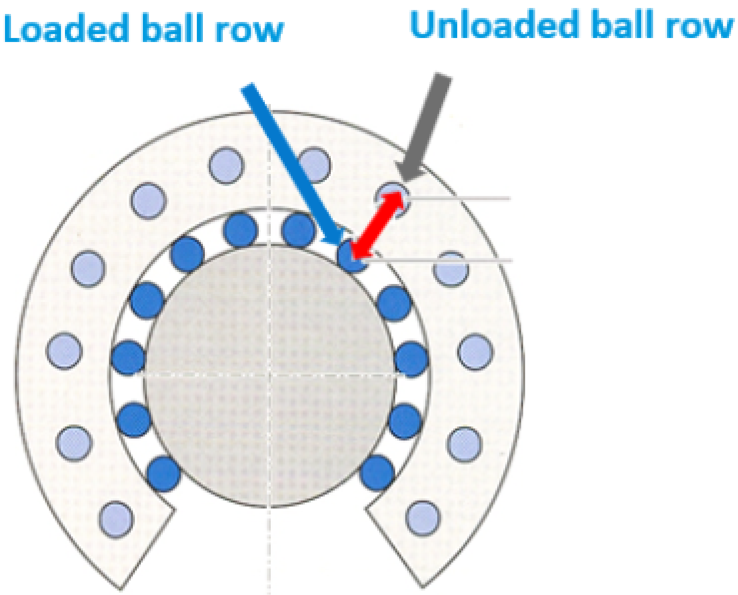
The minimal contact surface due to the point contact also results in an even lower friction coefficient between the rolling elements and the raceway compared to ball screw drives and linear guides. Ball bushing guides are considered to run very smoothly.

Deflection maps

There are two different deflection types for ball bushings: tangential and radial deflection. The type most commonly used today is the tangential deflection: The loaded balls are guided into the cage before they are subsequently returned unloaded and without contact to the shaft. The tangential deflection is the most compact design.

An alternative is radial recirculation, in which there are a large number of ball circuits, which – as with a rail guide – are returned in an end cap into a return bore in the nut body above the raceways. Although higher load ratings can be achieved with this type of recirculation than with tangential recirculation, this radial recirculation is no longer used in today's ball bushings due to the high costs involved. Especially since the development of the relatively inexpensive linear guides, their production is no longer profitable, which is why the radial deflection is hardly found on the market anymore.





The tangential deflection (left) is used today in both standard and super ball bushings, while the radial deflection (right) is no longer found in new products.

Areas of application

Ball bushings are suitable for applications where little load is moved and high precision is not required. Typical areas of application include office and packaging machines, but they are also commonly used in medical technology.

SNR brand ball bushings

As the products of individual manufacturers differ from one another, the following section will focus on a few products from the SNR brand.
Standard ball bushings in ISO dimensions are designed as single or tandem versions in closed, adjustable and open designs. Super ball bushings are only available in single versions in open and closed designs. In addition, standard cylindrical single ball bushings are available in JIS dimensions and closed design. The same applies to ball sleeves, another type of ball bush. Ball bushings can also be integrated into linear units, which are available in single, tandem and quattro designs and can be combined with both standard and super ball bushings. These are available in open, adjustable and closed form as well as in several other designs. Various accessories are also available for ball bushings, including shafts and clamping elements. More detailed information on SNR brand products can be found here.
If you are wondering what calculations are required for ball bushings or how they are installed, you can take a look at the other articles on linearwizard.com.

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Assembly of ball bushings

Assembly of ball bushings The installation of ball bushings is generally not complicated, on the contrary, it is fortunately relatively easy to carry out. There is therefore not a great deal to consider during assembly: It is only important to take the installation tolerances and ambient conditions into account. You can find detailed information on this as well as installation
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Calculation principles (ball bushings)

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 x 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 x 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

$L_h = \frac{L}{2 \times s \times n \times 60}$		$L\# = \frac{L}{2 \times s}$	
L_h	Nominal service life (m)	$L_\#$	Nominal service life (cycles)
s	Stroke (m)	s	Stroke (m)
n	Number of strokes (min^{-1})		

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!

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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
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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
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Assembly of ball bushings

The installation of ball bushings is generally not complicated, on the contrary, it is fortunately relatively easy to carry out. There is therefore not a great deal to consider during assembly: It is only important to take the installation tolerances and ambient conditions into account. You can find detailed information on this as well as installation instructions in this article.

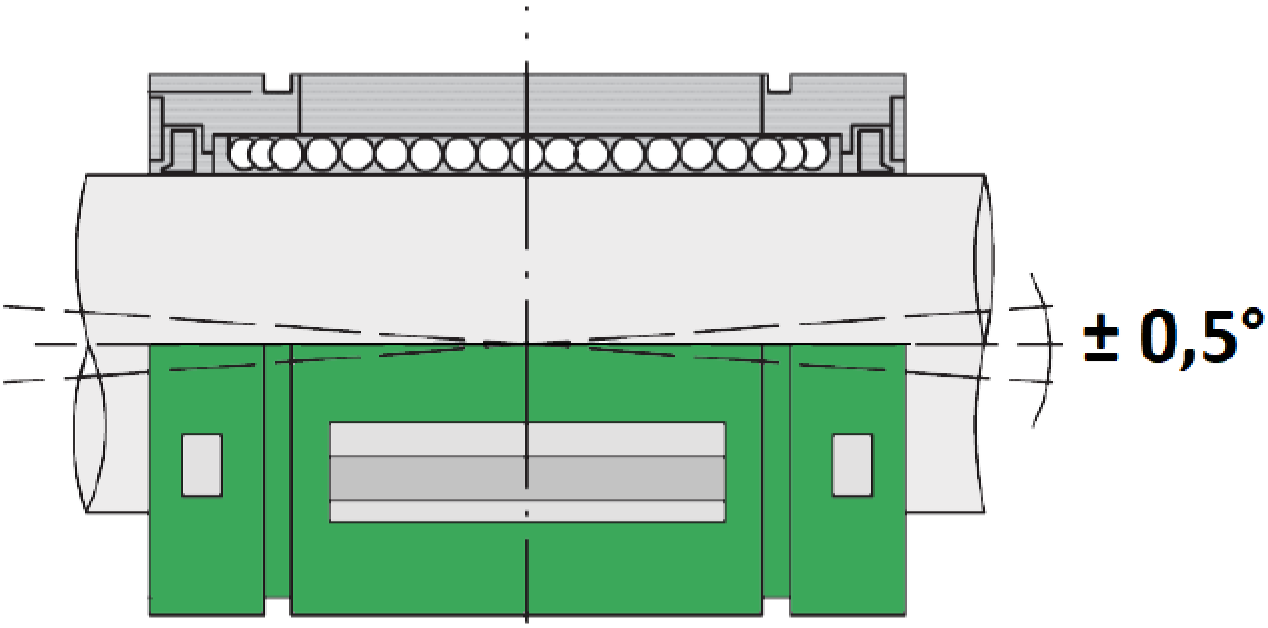
Assembly tolerances

In connection with the assembly of ball bushings, a few tolerances must be considered, which firstly depend on the type of ball bushing, i.e. ISO, JIS, super ball bushings and ball sleeves. The tolerances relate to the shaft diameter on the one hand and the housing bore diameter on the other.
Although there are various recommendations for the shaft diameter, an h6 shaft is recommended in most cases: To be precise, this is the standard recommendation for JIS and super ball bushings as well as for ball sleeves, while the h6 shaft is generally used for ISO ball bushings in applications with little or no clearance.
With regard to the housing bore diameter, i.e. the housing into which the ball bushing itself is mounted, an H7 bore can be named as the classic tolerance for a clearance fit. In applications with reduced clearance, a bore of size J7 is recommended.

	Shaft diameter		Housing bore diameter	
	Clearance fit	Transition fit	Clearance fit	Transition fit
ISO Ball Bushings	g6	h6	H7	J7
JIS Ball Bushings	h6	j6	H7	J7
Super Ball Bushings	h6	-	H7	-
Ball Sleeves	h6	-	H7	-

In this overview you can see the respective recommendations regarding shaft and housing bore diameters, considering the types of ball bushings.

Bending of the shafts

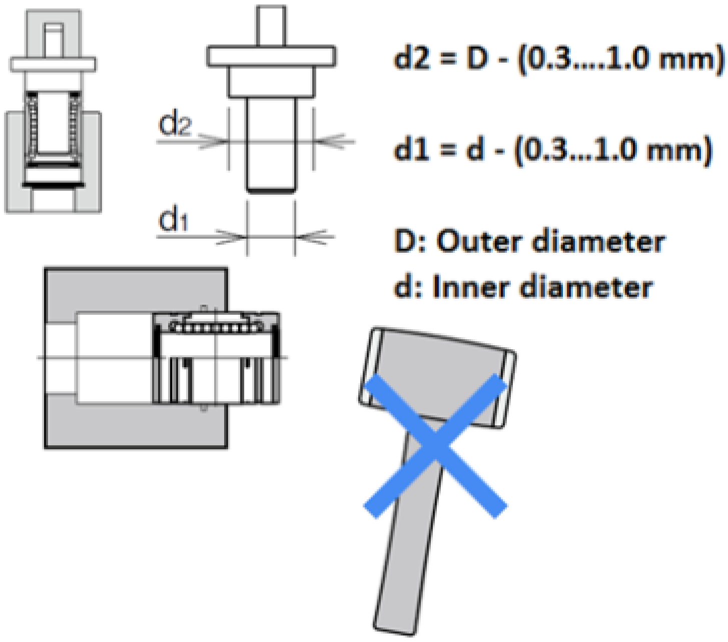


Many super ball bushings have the advantage that they can compensate for certain angular errors.

If long steel shafts are used as self-supporting shafts with closed ball bushings or if a shaft is subjected to too much load, there is a risk of bending of the steel shafts. As soon as these bending exceed permissible limits, reliable function can no longer be guaranteed as high peak loads occur at the ends of the ball bushings. On the one hand, the ball bushing then runs unevenly, and, on the other hand, the service life is significantly reduced. To counteract this tendency, there is a variant of the super ball bushings with tolerance compensation, which are able to compensate for angular errors of up to ±0,5°.

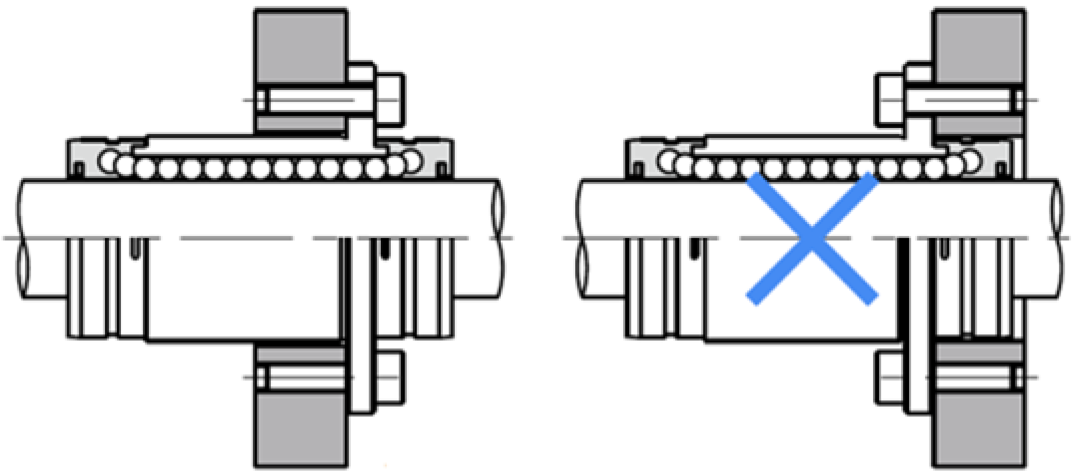
Assembly instructions

For mounting cylindrical ball bushings in housings, we recommend using an auxiliary tool that is adapted to the diameter of the ball bushing. This tool is required to carefully push the bushing into the housing. It is particularly important to note that only suitable auxiliary tools may be used.



Attention! Hammers are not suitable assembly tools for ball bushings.

If flanged ball bushings are to be fitted, it must also be ensured that they are carefully inserted into the housing. The ball bushing must only be fastened with the reference surface to the housing. This means that it is essential to ensure the correct installation direction: If it is installed the wrong way round, there is a risk of a bending moment acting on the ball bushing, which in turn can cause the flange on the ball bushing to break off, for example. If you want to install ball bushings in the unusual direction, this is possible with so-called reversing flange bushings; however, these are very rare on the market and are only used in specific applications.



In the sketch on the left, you can see the correct installation direction - please do not install in the opposite direction!

It is also important to pay attention to a few basic aspects when installing ball bushings on the shafts. Firstly, only deburred shafts may be used. Ball bushings must be carefully pushed onto the shaft and should not tilt. If parallel shafts are used, they must be aligned so that there are no misalignments between the two shafts.

Product selection

To round off this article, here are a few words on product selection, which is important in order to configure the right product for the installation. Of particular importance here are the criteria of *installation space*, *mounting options* and *environmental conditions*, which must always be considered in this context. The exact conditions involved can be seen in the table.

Installation space	Mounting options	Environmental conditions
• Possible system height • Possible system width • Number of parallel shafts • Number of ball bushings per shaft • Accessibility for maintenance	of the shaft: • Self-supporting, with shaft supports or with traverses • With support rails of the ball bushings: • Cylindrical ball bushing in a housing • Mounting via flange	• In case of pollution: Use ball bushings with a suitable sealing system • If aggressive substances: Use corrosion-resistant versions • If there are special environmental conditions, e.g. clean room: Selection of the optimal configuration (lubricants, seals)

With regard to installation space, mounting options and ambient conditions, there are a few things to consider when selecting a product.

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