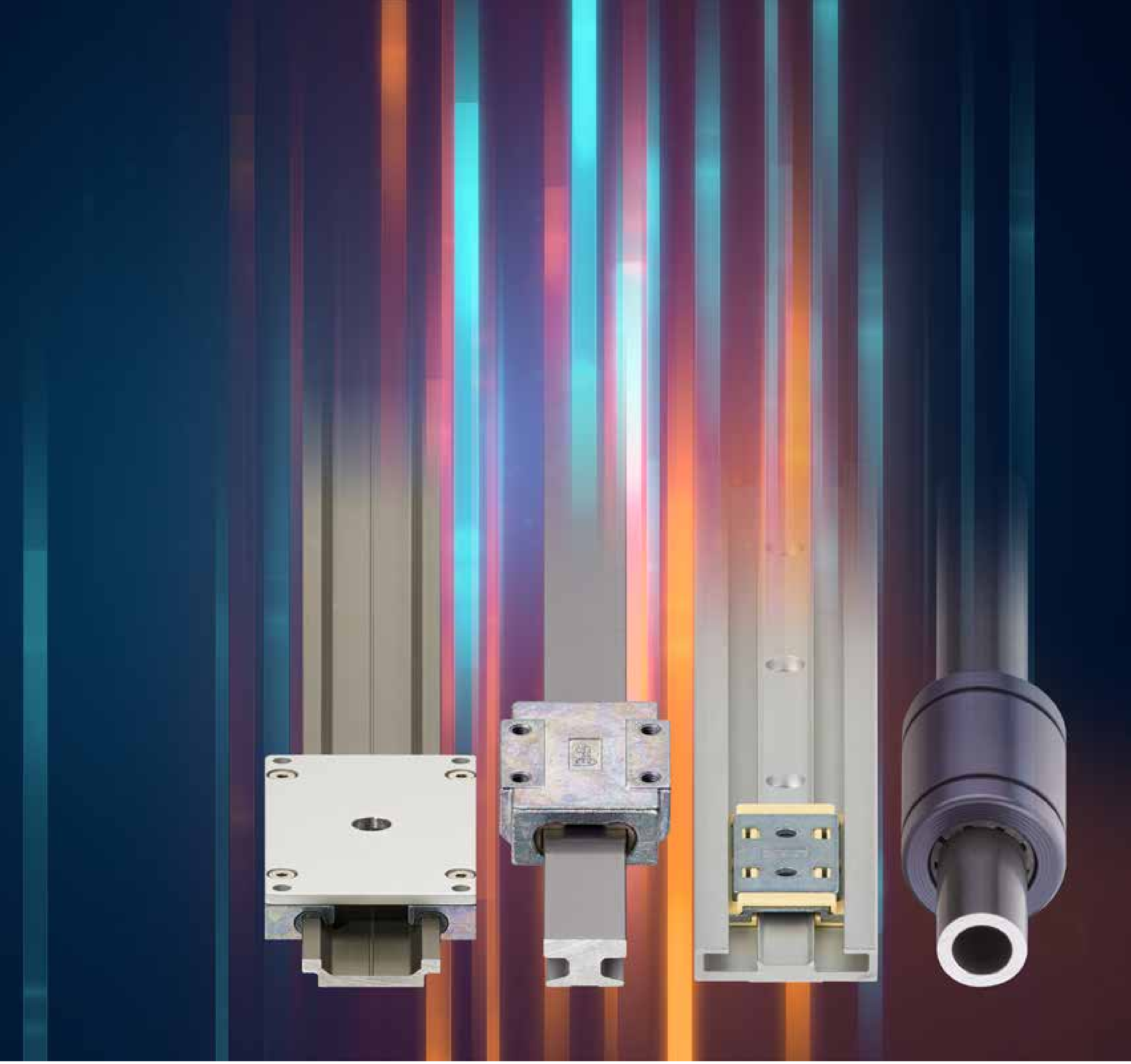


WHITE PAPER:

When to use plastic linear bearings and linear guides or recirculating ball systems

igus®

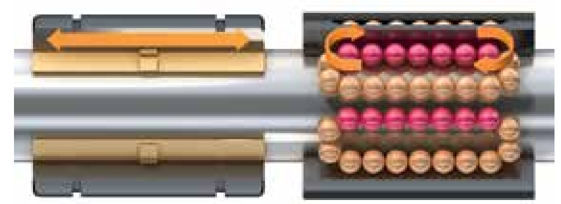
Source: igus® GmbH

Introduction

Linear bearings are machine elements that perform a linear movement. Rolling or sliding elements transmit the forces that occur. In this white paper, two linear guide concepts are compared: sliding on plastics as well as rolling by means of rolling elements made of steel balls. Both linear plain bearings and linear ball bearings take over the guidance and positioning in classic mechanical engineering as well as in automation. But when should we use a plastic plain bearing and a rolling bearing with steel balls? This white paper will provide support and a basis for making a decision regarding the right choice of the bearing, as the selection depends on a number of factors: on the one hand, the individual conditions of use such as what speeds are to be dealt with, how high is the load that acts on the bearing, or which stroke lengths must be completed. On the other hand, the ambient conditions of the bearing have to be taken into account. These include the prevailing temperature conditions or a potentially required dirt or media resistance. Every linear technology has characteristic properties that are suitable for specific bearing applications. For this reason, the criteria which are relevant for the respective application have to be determined in advance.

The functional principles

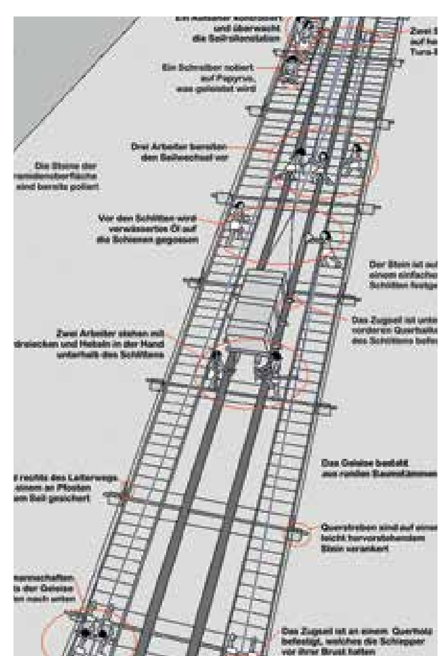
Linear guide systems can be divided into open and closed guides according to the shape of the guidance, and according to the direction of the transferable forces and into the plain bearing or rolling bearing guide according to the type of friction. In principle, a linear guide consists of two components, a leading and a guided part. The leading element is a profile rail or a round shaft. Guide carriages and round bushings are guided. The difference is in the type of bearing–either rolling or sliding translation. Both linear guide concepts are available individually as a unit, as well as in combination with linear drives as a complete assembly.



Source: igus® GmbH

History

The Egyptians pulled the stone blocks for their pyramids on carriages over hardened transport ramps. At that time a layer of mud and water served as lubrication, and the carriage and ropes performed the movement. The large contact area guaranteed a high static load bearing capacity, however this resulted in considerable resistance to movement. This was overcome by a massive application of human and animal strength. Metal plain bearings were used in the course of industrialization. With the aim of further reducing the friction and the necessary driving force, rolling bearings have been developed in which metal balls act as rolling elements. This technical innovation transformed the surface contact into a point contact. This results in a low-friction guidance while at the same time reducing heat generation. The wear and the requirement for lubricants were lower compared to metallic plain bearings. The rolling bearings were the linear guide of choice, until plastic technology revolutionized the plain bearing design. Modern polymer plain bearings operate without lubrication and show very good wear and friction properties. Today, rolling bearings and linear plain bearings stand side by side.



Source: https://www.cheops-pyramide.ch/image/schlitten-geleise/seilrollenstation-erklaerung.gif

The rolling bearing guide

Source: igus® GmbH

Most rolling bearings operate according to the principle of a recirculating ball bearing system, therefore also called recirculating ball bearing guides or recirculating ball bearings. Small steel balls are used as rolling elements, which move axially in a ball channel. The profile rail guides with recirculating ball bearing systems are differentiated by circular guides with ball bushings as well as rail-rail units with intermediate ball-shaped flat cages. In the case of the profile rail guide, the rolling movement takes place by means of a rail and a ball guide carriage running on it. The carriage guides the recirculating steel balls, which are stressed in the direction of movement via the inner ball guide row, deflected, and are guided back within the carriage into the raceway in a load-free manner against the axial movement. This recirculation principle ensures that all balls are evenly loaded. The small contact surface of the rolling elements with the elements of the guidance leads to very low friction. Due to the point contact and the associated high pressures on bearings and shafts, only hardened rails and shafts made of steel or stainless steel can be used. The ball rail guides can be provided with two, four or–for very high loads–six-row orbits. The balls usually consist of steel, but ceramics are used when high speeds are required. The runner blocks can be made of steel, carbon steel or aluminum. In the case of ball bearing guides, the rolling movement takes place by means of recirculating rows of balls in a bushing on a round shaft. This form is the most widely used linear guide. Recirculating ball bearing guides can handle different stroke lengths. Their installation dimensions as well as guide tolerances have been internationally standardized so that switching between the different manufacturers is possible. Mechanical wear and fatigue of the material can result in damage to the rail known as pitting, developing on the raceways and balls, which reduce the service life. This manifests itself initially in an inaccurate guidance leading to the failure of the system.

The linear plain bearing guide

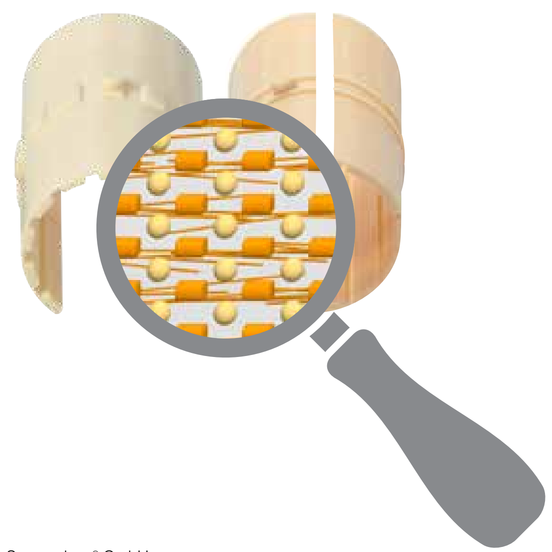
The concept of linear plain bearings differs from that of the linear bearings with recirculating ball bearing system in the nature of movement; plain bearings do not roll, they slide. The bearing elements are not separated from each other by rolling steel balls, but are sliding directly on the rail or shaft without a rolling element. This gives a larger contact surface resulting in lower surface pressure. Due to the large surface-load distribution in comparison to recirculating ball bearing systems, low-cost soft shaft materials such as aluminum and non-metallic components, as well as hardened stainless steel or hard chromium plated steel, can be used in linear plain bearings. In order to reduce the friction, plastics optimized tribologically for friction and wear are applied on the sliding surfaces. These high-performance plastics consist of a thermoplastic base material which ensures good wear resistance. In order to increase the mechanical load-bearing capacity, fibers and fillers are added to the matrix. High-performance materials–made of various fibers and materials each with specific properties–can be mixed to make specially developed thermoplastic compounds. The advantage of plastics is that they can be developed for specific properties. Depending on the requirements, linear liners that are resistant to pressure and wear as well as media and temperature can be produced. In addition, by selecting the suitable material pairing of sliding surface and shaft or rail, the coefficients of friction of the plain bearings can be positively influenced and their service life extended. The polymer component can be fitted to the guidance, the guide carriage or as a liner between the components. There are also sliding bushes made of solid material. In contrast to metal composite bearings, polymer plain bearings are not constructed in layers but as a homogeneous structure. In this way, the entire bearing wall thickness acts as a wear zone. A layer structure, on the other hand, can lead to the sliding of the gliding layer on the next layer. As a result, the coefficient of friction and wear rates increase. Due to their homogeneity, plastic plain bearings have a consistently low friction coefficient throughout the service life and a very good wear behavior.

Source: igus® GmbH

The materials

In addition to the design, the materials used in the bearings are selected for their suitability for a specific application. Metals are of great importance in mechanical engineering due to their high strength, plastic deformation, and their good electrical and thermal conductivity. They can be melted and cast. The properties of the different metals refer to the nature of their chemical bonding and the cohesion of the atoms via the metallic bonding, whose electrons move freely in the metal lattice. Steel is referred to as iron-carbon alloys, which have a carbon content below 2.06 percent. It is the most commonly used metallic material. By virtue of their chemical composition steels can be classified into alloyed or unalloyed, or according to their application requirements, into basic, high-quality or stainless steels. Alloys can change the properties of the steels in many ways. The material additives such as aluminum or stainless steel make the metals more resistant to external influences. By hard anodizing aluminum, it achieves extremely high wear resistance and surface hardness. In addition, aluminum has good formability, and for this reason is used as a construction profile for lightweight construction. Its disadvantage is the high cost. Corrosion-resistant steels such as stainless steel can resist chemical substances and corrosion to some extent. They have good strength properties, are heat resistant and easy to clean.

The difference between plastics compared to metals lies in their internal structure. This refers both to the chemical bonding and to the structural arrangement of the molecular chains compared to the lattice structure of metals. As with the metals, the properties of the plastics depend on the particle types involved as well as the bonding forces between the particles and their structural organization. But in the case of plastics, the atoms and ions do not determine the properties of the particles but the organic macromolecules. These can differ within a plastic in terms of their size and chemical structure, which changes its specific property. Due to their low density, the strength and stiffness of plastics are weaker than of metals. It can be compensated by structural means such as larger wall thicknesses or the addition of fibers and fillers.



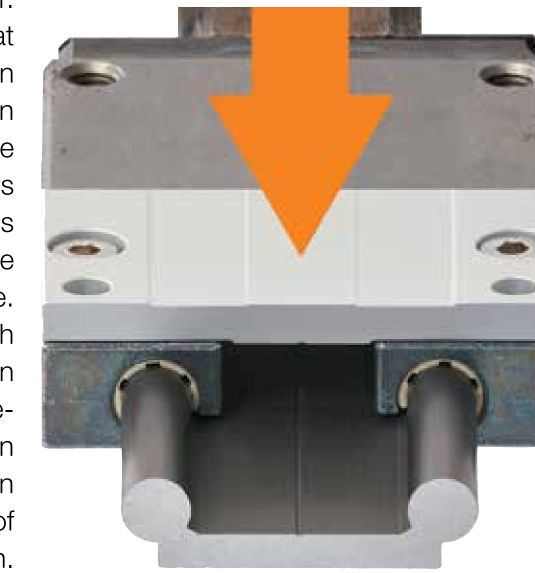
Source: igus® GmbH

The linear guides in comparison

As a result of the different technical principles and materials, both rolling guides and linear plain bearings have their strengths and weaknesses, which are decisive for the choice of the linear guide. The properties of linear plain bearings and linear ball bearings which are relevant with regard to their application are subsequently compared with one another.

Lubrication versus dry operation

A significant difference between linear plain bearings made of plastic and rolling guides made of metal is the use of lubricants, which is closely linked to the subject of friction and wear. In Germany, the damage caused by friction and wear are estimated at around 30 billion euros (31 billion USD) per year. In order to reduce friction as well as corrosion, the two-way contact of the steel rolling elements in rolling bearings requires a permanent lubrication with grease or oil. The recirculating ball bearing system ensures that the amount of lubricant is evenly distributed. However, a linear bearing that has to be lubricated is susceptible to maintenance: approximately every three to six months the guide carriage has to be re-lubricated via an adapter or a grease nipple. The lubrication intervals are short, especially with high loads and high speeds. If only a low lubricant supply is required, lubrication devices can extend the lubrication intervals. Also, lubricant reserves in the cavities between the balls or lubrication pockets incorporated in the recirculation can keep up the lubrication over the duration of the use. Ball raceways can also be supplied with lubricant via ducts. Nevertheless, 38.5 percent of all rolling bearing damage is caused by a lack of or incorrect lubrication. In addition, lubricated rolling bearings are sensitive to dust and dirt. The guides can be agglutinated, the sliding parts welded together, and break loose (corroded) due to insufficient lubrication. Higher quality rolling bearings are therefore equipped with scrapers or guards for environments with gross dirt and chips. Longitudinal or end seals as well as cover strips can prevent the penetration of contaminants into the interior of the ball carriage and thus extend the service life. However, the sealing elements increase friction and are very sensitive. If the lubrication is not sufficient, the sealing elements become brittle and get cracks. Then, dust penetrates into the housing and blocks the guidance. This requires time and money, first for cleaning: in order to free sticky rails or shafts from dust and dirt, they have to be cleansed, often using high-pressure cleaners and aggressive cleaning agents. Scrapers and gaskets do not withstand solvents in most cases. Second, the machine is at a standstill during this time and the production fails.



Source: igus® GmbH

Maintenance-free self-lubrication effect

Linear plain bearings made of plastic, on the other hand, operate completely without external lubrication. They operate dry–without oil or grease. Microfine solid lubricants are embedded in minute chambers in the matrix of the high-performance polymers. As soon as the linear guide moves, homogeneously distributed solid lubricant particles are released by the micro-abrasion, which settle in the microscopic troughs of the shaft surface and lubricate the guidance itself. Plain bearings and shaft operate without an apparent lubrication film. After the running-in phase, the micro-abrasion decreases so that long distances can be covered with a low sliding coefficient and very low wear. Due to the self-lubrication effect, plastic plain bearings do not have to be serviced, so machine downtime is reduced and productivity is increased. The self-lubricating design also offers the advantage that linear plain bearings can also be used openly in adverse environmental conditions. Dirt or dust particles such as those that occur, for example, in the wood industry, cannot stick to lubricants or are pushed forward from the bearing during the next movement. Furthermore, liners with specific geometries act as dirt channels which push out the foreign bodies–such as wood chips or metal chips–from the guide track without hindering the operation of the plain bearing. Dry-operating linear bearing systems are extremely clean and hygienic, such that numerous polymer plain bearings are certified for cleanroom compatibility according to the ISO certification of the Fraunhofer Institute for Production Engineering and Automation. Self-lubricating linear plain bearings are also suitable for use in the food industry, since it cannot lead to contamination of foodstuffs and plastics are resistant to harsh disinfectants.

Precision

The special strength of the rolling guide is its high precision. As the number of rows of rolling elements increases, the load bearing capacity and the stiffness of the profile rail guide increase as the loads are supported by more rolling elements. However, friction and wear also increase. Preloaded runner blocks increase the stiffness as well as the accuracy of the guidance system. The bearing clearance, which is achieved by precise manufacture and the applied preload, is about 0.001 mm to 0.01 mm for linear rolling guides. The preload is given depending on the dynamic load rating "C" and is divided into accuracy classes. In these classes the height accuracy, the lateral accuracy, the parallelism as well as the running accuracy of a profile rail guide are combined. Depending on the requirements of the bearing application, the appropriate accuracies can be selected. At the same time, the displacement resistance–and thus the service life–of the profile rail guide is also influenced.

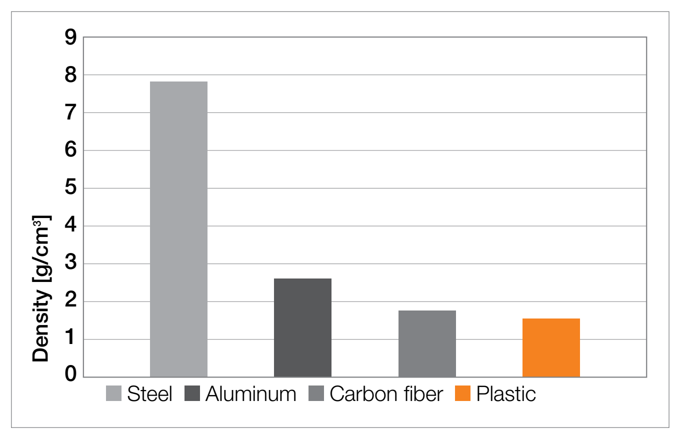
Source: igus® GmbH

Since linear plain bearings must always have a minimum clearance in order to counteract a braking effect, polymer plain bearings achieve a maximum bearing clearance of 0.02 - 0.15 mm. For this reason, their use in machine tool manufacturing, CNC machining or electronic production is not recommended.

Weight

Low weight is beneficial in designs where every gram counts, as in the automotive and aircraft industries. It is also useful when it comes to dynamic applications and the increase in the number of cycles as in handling or automation tasks, since it increases acceleration and thus increases productivity. Heavy metals such as non-alloyed steel also have a very high weight due to their high density of around 7.8 g/cm³. In this regard, linear guide systems made of plastic perform better. The density of most plastics is between 0.8 and 2.2 g/cm³. They are roughly five times lighter than steel and still display good toughness. The benefit: the less mass you have to accelerate, the less energy you use.

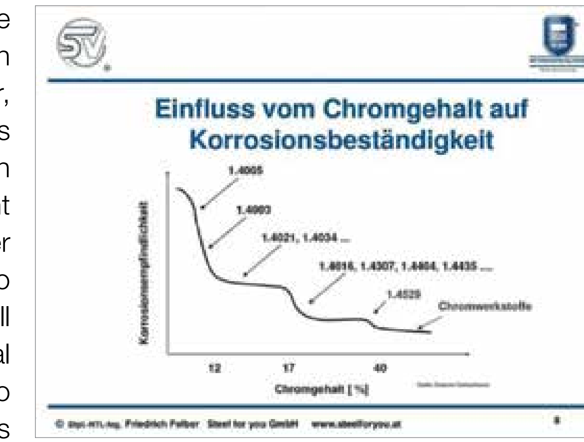
A further aspect is that linear guide systems are more flexible with respect to rolling bearings in the choice of materials. They can run on soft and non-metallic shaft or axis materials. Aluminum is lighter than steel, for example, with around 2.7 g/cm³. The resulting low mass ensures easy handling. A linear guide that slides on non-metallic shafts–for example on carbon-fiber reinforced or glass-fiber reinforced plastic–is once again 40 percent lighter than aluminum bearings and 60 percent lighter than a guidance with steel rail. The flexible use of plastic solutions is also useful wherever physical loads are reduced or transport costs have to be reduced, such as in the furniture sector, in 3D printers or in mobile applications such as camera technology.



Source: igus® GmbH

Corrosion protection

In contact with water, steels begin to rust by the oxidation with oxygen. This corrosive process can seriously affect the operation of a component. For this reason, many rolling guides use stainless steels, which have significantly better corrosion resistance than low-alloy and unalloyed steels. To some extent they also withstand aggressive media and do not require additional surface protection. These non-rusting, corrosion-resistant stainless steels are listed under the general term stainless steel. Their corrosion resistance depends on the carbon content (C) as well as on the alloy percentage of chromium (Cr). Stainless steels are referred to as steels which have at least a Cr content of 10.5% and a C content of a maximum of 1.2% by weight. The most common stainless steel is the 304 stainless steel with the material number 1.4301. These stainless steels are classified according to their chemical composition into four groups, each of which is related to their microstructure: 1. Ferritic, non-rusting steels with a C content below 0.1 percent and a chromium content between 10.5 percent and 30 percent, 2. The martensitic steels (Cr 12% -18%, C 0.05% - 1.2%), 3. The austenitic steels (Cr 16% -28%, C 0.02% -0.1%) and 4. The austenitic-ferritic steels, also called duplex steels (Cr 21% -26%, C to 0.03%). The highest corrosion resistance is found in stainless steels with low carbon content and a chromium content of more than 17 percent–the austenitic steels. Additives such as nickel or molybdenum can further increase their corrosion resistance. However, the austenitic steels–1.4301, 1.4305, 1.4571, 1.4404–have the disadvantage that they cannot be hardened. They are therefore not suitable for use in rolling guides, since these can only run on surface-hardened shafts, as mentioned above. However, steels that can be hardened–for example the material grades 1.4034, 1.4112, 1.4125–have a comparatively high carbon content with more than five percent and are corrosion-resistant only very conditionally. Polymer plain bearings, on the other hand, do not rust. They are absolutely corrosion-free. Due to their organic nature, they are resistant to inorganic media as well as mineral acids, alkalis and salt solutions. In addition, special plastics have a low moisture absorption, which allows them to be used in the underwater sector. Since polymer plain bearings can slide on soft shafts, corrosion-resistant austenitic materials can be installed in linear plain bearings made of high performance plastics. A guidance with a shaft made of high-alloyed steel such as 1.4571 in combination with a plain bearing made of high-performance polymer is suitable for cleaning-intensive industries such as filling technology, chemical and electroplating industry or in seawater, such as in the offshore sector.



Source: http://www.steelforyou.at/0uploads/qs.pdf – Slide 8

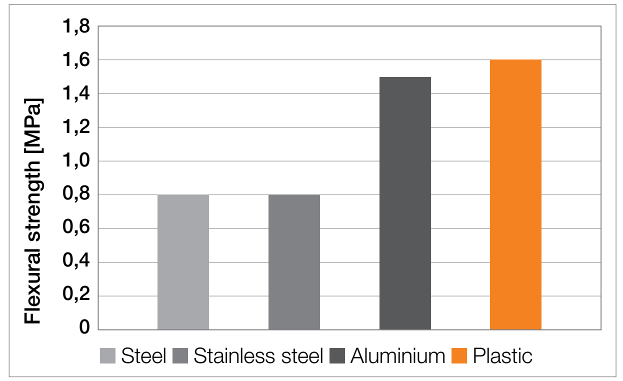
Speed

Machine elements must be moved quickly and in a straight line. For this reason, linear bearings must be able to withstand high speeds and accelerations. Due to the inertia of the rolling elements, the maximum speed of rolling bearings is between 5-10 m/s. Plain bearings, on the other hand, reach up to 30 m/s and also perform better in terms of acceleration, however, only when small masses up to a maximum of 10 kg have to be moved. Otherwise the friction heat caused by the higher contact pressure during the sliding movement will interfere with the function. When using hard-coated aluminum as a friction partner, the operating temperature in the bearing point can be reduced by the high thermal conductivity of aluminum. Thus, significantly higher loads and speeds can be implemented. In the case of linear plain bearings, there is also no noise-intensive collision of the balls, which makes them suitable for applications in the high-frequency sector, for example in the textile industry.

Source: igus® GmbH

Loads and impacts

Guide systems can absorb high static loads due to the uniform distribution of the force on the load bearing surface. The extent to which these specific loads can occur depends on the maximum permissible surface pressure. Plain bearings made of thermoplastic polymers with embedded solid lubricants can handle bearings with surface pressures of up to 150 N/mm². The fiber matrix of thermoplastic compounds does not yield even with radial pressures. The dampening properties of the plastics also make them relatively insensitive to impacts, vibrations and shocks. In addition, the elastic properties of polymers prevent permanent deformations. In comparison, the soft and thin gliding layer of the metal bearings can be easily pushed away under high loads, edge pressures or vibrations, so that the coefficients of friction and wear increase, leading to a failure.

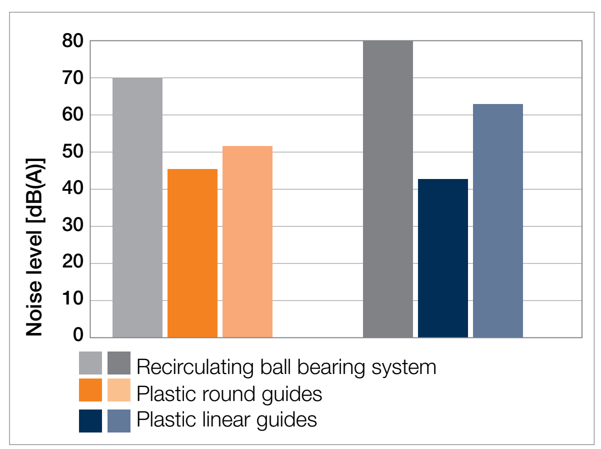


Source: igus® GmbH

Source: igus® GmbH

Noise dampening

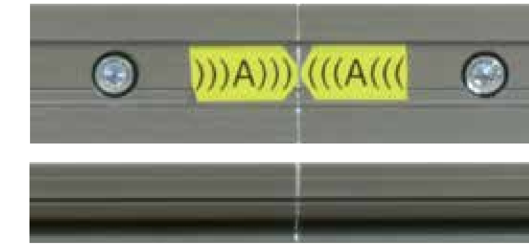
Low-noise linear bearings are gaining in importance, as bearing solutions are increasingly used in working and recreational environments. Particularly in medical and laboratory technology, in furniture construction or in office-compatible 3D printers and fitness machines, low noise is indispensable. The rolling system of the rolling bearings causes noise and vibrations due to the collision of the balls. Since polymer plain bearings do not roll on metal bodies, but glide on the shaft without jolts and vibrations, they are quieter than metallic linear bearings. The decibel values lie between 45 and 60 dB(A) for plain bearings, whereas between 60 and 70 dB (A) for rolling bearings. In addition, in contrast to recirculating ball bearing guides, the db values do not increase for linear plain bearings, even with increasing speeds. In rolling bearings, the noise of the rolling balls can be reduced by means of a ball chain, in which plastic elements keep the balls at a distance.



Source: igus® GmbH

Stroke lengths

In order to achieve greater stroke lengths, guide rails are lined up in a row. In the case of linear plain bearings, the rails are slightly chamfered at their ends and placed one behind the other. The grooves produced by bumps can be easily passed over by the sliding elements. Rolling guides, on the other hand, are mortised, measured and aligned in order to make the crossovers precise and to avoid damage to the shield and the balls.



Source: igus® GmbH

Ball guides require a minimum stroke length so that all balls can be inserted and the lubricant can be recirculated. For very small strokes, the same balls are always in contact with the shaft in rolling bearings. As a result, they are stressed on one side, which impairs the service life. In short distances, the linear plain bearings are therefore more impressive because they operate independently of the stroke length at 2 mm as well as at 30 m.

Coefficient of friction

The rolling friction is ten times lower compared to the sliding friction. Since the coefficient of friction of the linear plain bearings is higher than that of the rolling guides, the required drive force is consequently also higher. This fact must be taken into account, especially in manually operated applications.

In order to avoid the possibility of an uneven movement sequence or blockage of the system, the position of the drive must be precisely planned for linear plain bearings. The greater the distance between the drive and fixed bearing, the higher the degree of wear and required drive force. Therefore, the 2:1 design rule should be applied: if the distance of the driving force to the fixed bearing is more than twice the bearing spacing (2:1 rule), the guidance will theoretically get stuck at an adhesion friction coefficient of 0.25. Thereby, this principle applies regardless of the value of the load or drive force. It is only the product of friction and the ratio of the distance between the driving force and the bearings, and always refers to the fixed bearing. On the other hand, the rolling bearing guides are more flexible in the construction because of their lower coefficient of friction.

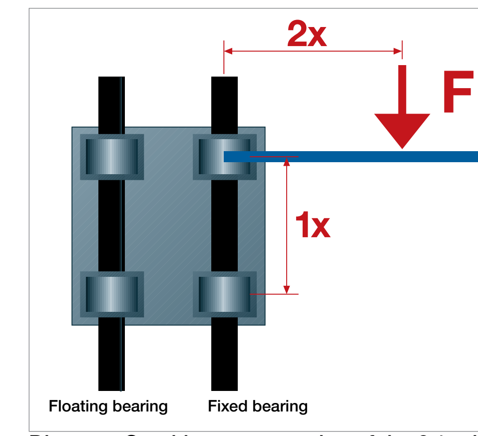


Diagram: Graphic representation of the 2:1 rule

Source: igus® GmbH

Costs

The production of polymer sliding elements using the cost-effective injection molding process as well as completely injection-molded plastic bearings is economical. Plastic production is more energy-efficient than metal production. Metals must be cast extensively at high temperatures. In addition, there are restrictions with regard to the casting molds, whereas more complicated moldings can also be produced from thermoplastics with relatively little effort. At the same time, in a processing step, further additives such as color pigments or fibers can be incorporated into the material, which would decompose at the high temperatures involved in metal casting or sintering of ceramics. Even extruded, coated aluminum rails are more cost-effective to manufacture than the multi-pressed, ground and finally hardened profile rails made of steel or stainless steel used in rolling bearings.

In Germany, a million tons of lubricating oil are sold annually. By dispensing of external lubrication, the costs for lubricants can be saved. Moreover, the production costs can also be reduced, since the maintenance-free, dry-operating linear plain bearings significantly reduce machine downtimes. Overall, plastic plain bearings can reduce the costs of metal solutions by 40 percent. Savings are made in the purchase and in the operation.

At a glance

Table of Properties of Plain Bearings and Rolling Bearings (System comparison of igus® plain bearing vs. rolling bearing)

	Characteristics		Technical data		
Properties	igus® bearings	Rolling bearings	igus® bearings	Rolling bearings	Especially relevant for the following industries ...
Precision	+	+++	0.02 - 0.15 mm	0.001 - 0.01 mm	Machine tools, CNC processing, electronics manufacturing
Completely self-lubricating	+++	+			Medicine, packaging, food, clean room, consumer goods
Maintenance-free	+++	+			For many different branches of industry
Weight advantage	+++	+	Alu approx. 2.7 g/cm³ Polymer approx. 1.5 g/cm³	Steel ca. 7.8 g/cm³	Handling, automation, laboratory, leisure time
Highly dynamic responsiveness in the case of low loads	+++	+			Packaging, handling, automation
Highly dynamic responsiveness in the case of high loads	+	+++			Packaging, handling, automation
Stroke length variance	+++	++			Camera technology, textile
Coefficient of friction	+	+++	0.15 - 0.3 μ	0.001 - 0.05 μ	Manual adjustment, pivoting motions
Resistance to dirt	+++	+			Packaging, stone, textile, paper, painting equipment
Noise dampening [1]	+++	++	45-60 dB(A)	60-70 dB(A)	Medicine, laboratory, furniture
Cost advantage	+++	++			For many different branches of industry
Corrosion protection	++	+			Filling systems, chemicals, food
Magnetism	+	+++	Plastic, aluminum	Steel	Medicine, testing instruments
Chemically resistant	+++	+	1.4571 + iglide® X	1.4112	Medicine, food, electroplating, filling systems
Compatibility of the modules	+++	+			Jig construction, assembly line automation
Quiet operation without any vibration	+++	++			Camera technology, inspection, medicine, 3D printer
Short-stroke suitability	+++	+			Textile, handling
Easy assembly and quick replacement	+++	+			Jig construction, assembly line automation
Rigidity	+	+++			Machine tools, CNC processing, electronics manufacturing
Long travels of more than 10 m	++	+			Camera, material handling, logistics
Temperature resistance	+++	+	up to +250 °C		Chemicals
Smooth running	+	+++			Manual adjustment
Maximum acceleration[2]	+++	++	50m/s²	15m/s[2)]	Automation, handling
Maximum speed[2)]	+++	+	30 m/s	5 - 10 m/s	Automation, handling

[1)] Measured in the igus® laboratory, 400 mm stroke, manual adjustment [2)] When subjected to low loads, depending on installation size 0.1 to 5 kg Characteristics: +++ strong ++ average + weak

Source: igus® GmbH

Conclusion:

Certain industrial requirements need different linear guides. The bearing selection procedure is based on previously defined criteria. If machine elements have to work with millimeter accuracy, and high precision and low friction are indispensable, then rolling bearings should guide the linear movements. In the interior of machine tools, machining centers or even in the assembly of printed circuit boards in electronics manufacturing, rolling guides cannot be replaced because of their very high precision and stiffness. However, if the accuracy plays a minor role, and factors such as dirt resistance, corrosion resistance or jerk-free movements are required, a linear plain bearing made of high-performance plastic is the first choice. Even in sensitive applications such as medical technology, the food industry, in the clean room or in dusty and dirty environments, recirculating ball bearing systems can be replaced by the more cost-effective linear plain bearings made of plastic. Furthermore, research and development, especially in the field of tribology, is still advancing. The continuous development of plastics is steadily increasing the performance limits of plastics. New materials, mixtures and methods of compounding open up new fields of use beyond the classical fields of application and extend the application potentials of linear plain bearings to the immediate living environment. Polymer plain bearings are the ideal solution, particularly for applications in mobile devices, in the workplace, in the leisure industry, in laboratory technology or in furniture, wherever smooth running and a low overall weight are decisive.

Contact

Kevin Wright
Country Manager, Canada
Phone: 800.965.2496
e-mail: kwright@igus.net

www.igus.ca/drylin