Linear bearings give new meaning to riding the rails

How to choose a linear rail and carriage for linear motion

Linear rail tutorial

The way you look at linear bearings can change the way your motion products appear, and more importantly, the way they behave.

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Linear rails come in basically two types, round and square. The criteria for choosing one over the other is no different than choosing any other machine component; spec out the design, define the system's objectives, and work from past successes and mistakes. But anyone short on experience can make more mistakes, so a condensed course in selecting the proper rail for any application to keep design errors to a minimum is in order. The best place to start is learning the fundamental characteristics of each type, and adopting those that are most relevant to the application.

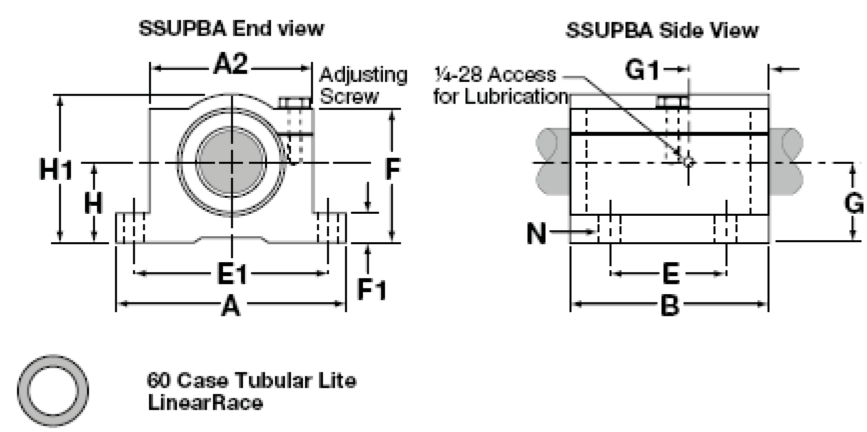
Round-rail technology has been honed to near perfection over the past 60 years and square profile rails a respectable 35. Both have definitely matured and most of the inherent design problems have long been ironed out. Materials have improved dramatically and the finest engineers have shaped linear rail technology into an "exact science." Most problems arise from misuse and misapplication. And the main reasons for misapplication often come from a personal bias or prejudice, a miscalculation, or an esthetic judgment. That is, a relatively small linear profile rail might fit the load, speed, and every other requirement just fine, but when it's mounted to the machine, a discerning eye might conclude that it looks feeble, definitely undersized.

One type of linear ball bushing guide is not necessarily easier to use than another, the choice depends entirely on the specific application. In general, a particular square-rail component might cost more than the round, but other requirements and the total system cost need to be addressed. At a minimum, these items include the expenses for preparing the machine bed (or other mounting surface) to accommodate the rail system, the positioning accuracy needed, and the total spatial environment available for the linear rail subsystem.

But before committing pencil to paper or mouse to pad, decide upon either a square or round rail. When the application looks like it could go either way, run preliminary calculations on the most critical characteristics and requirements gleaned from the following discussion and manufacturer's catalogs to make certain nothing is overlooked.

Round Rails in General

Before the advent of square rails, round rails were expected to satisfy every linear motion control situation. And for many, they did so admirably. But as machine tool users demanded closer tolerances for certain jobs, the machine makers favored the classical method of milling and scraping ways. Round rails were used for peripheral equipment when they couldn't meet the machining center's tolerance requirement.



Anatomy of a Linear Component

Linear ball guides come with a standard envelope and are interchangeable in all accuracy classes and preloads. This eliminates the need to match carriages and rails before installation. Calculations include static and dynamic loading under simultaneous conditions of pitch, roll, and yaw.

But by no means did this situation make round rails less valuable or obsolete. Their benefits overwhelmingly continue to outweigh their drawbacks. Round rails are generally less expensive than square rails, but that should not be the primary criterion for any application. In fact, selecting a square rail because "it costs more so it must be better" doesn't fly here. A square rail can actually fail in a particular application where a round rail can work smoothly and flawlessly. For example, round rails are more forgiving of misalignment, poor parallelism, and moment loads in most machines. Round rails also allow somewhat more variation in rail height than square rail systems. Even at that, they can hold a travel straightness of 0.001-in. for 10 ft, excellent for most applications. Also, the small rolling element tends to make the round rail motion smoother. To achieve this accuracy, they need supports only at the ends, although many are supported at several points or along their full length. This lets the rails cross over gaps without a problem, and safely go from one support to another. When the round rail system requires only a shaft rail assembly -- a shaft, a rail, or a shaft and two end-supported blocks with four pillow blocks -- the preparation cost is less than the square rail. Round rails don't need the same mounting rigidity as do square rails.

Generally, round-rail installation is relatively easy and inexpensive. And service and replacement favors the round rail. By comparison, any one component can be replaced in the round rail assembly without affecting the other components, but the entire profile rail assembly must be changed when worn.

Square Rail Introduction

Square rails were initially designed for the machine tool industry. They replaced the machine's integrated carriages and ways, which are integral areas of the machine bed in many machines. Notwithstanding, some traditional carriages and ways are still needed for high accuracy in certain situations. But the square rails found their way into machine peripherals then, because they were smaller than the round rails that were doing the job before square rails came on the scene.

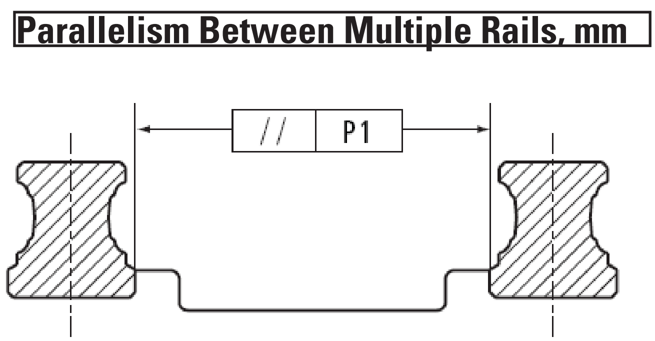
In addition to initially being targeted for machine tools, the square profile rail system displaced an assortment of round rails in the machine tool industry. Square rails are stiffer and more rigid, but need straight, continuous support with

It's in the catalog

Most manufacturers' catalogs for linear roller and ball guides contain the necessary application and engineering information for sizing and installation. These are the parameters required for determining the dynamic load and moment ratings and the static load and moment capacities, which include pitch, roll, and yaw. It also includes graphs and equations for determining bearing travel life from the dynamic load rating and applied dynamic load input parameters. Each linear roller or ball bearing guide has specific or unique specifications for velocity, acceleration, tolerances, preload, and temperature range.

The most critical parameter for profile guides is running parallelism, which is in the several-micrometer range. Unless followed closely, the bearings bind or wear prematurely, and the result could be misinterpreted as an inferior product. To prevent such problems, the installation guide painstakingly covers the subject of mounting-surface preparation, mounting tolerances, and rail parallelism. Installation data also discusses rail vertical offset, vertical and lateral carriage offset, mounting-hole tolerances, bolt torque, and butt joints. Numerous additional parameters are covered in the engineering section, including sizing and defining guide characteristics, applied loading calculations, and preloading.

Round linear ball bushing bearings require the same considerations as profile rails, plus a few. Polar graphs illustrate the dynamic load capacity, and graphs show the load life. The low friction coefficient of 0.001 and self-aligning specifications given to round rails eliminate the need for the derating factors commonly assigned to profile rails.



Square rails are required to have extremely parallel surfaces to prevent binding and excessive wear. They tend to take on the shape of the mounting surface so strict adherence to the parallelism specifications is necessary.

tight requirements for flatness and parallelism; they can't span the gaps that a round rail can. But because machine manufacturers are accustomed to precision bed preparation, it's not a problem. They frequently prefer the smaller, stiffer, square rail system over the round rail.

Square rails can cost less when higher load capacity in a smaller package for a limited space is considered. But the size of the square rail might have to be increased, just because of aesthetics. It could look like a misfit when it's deemed relatively too small in comparison to the rest of the machine's size.

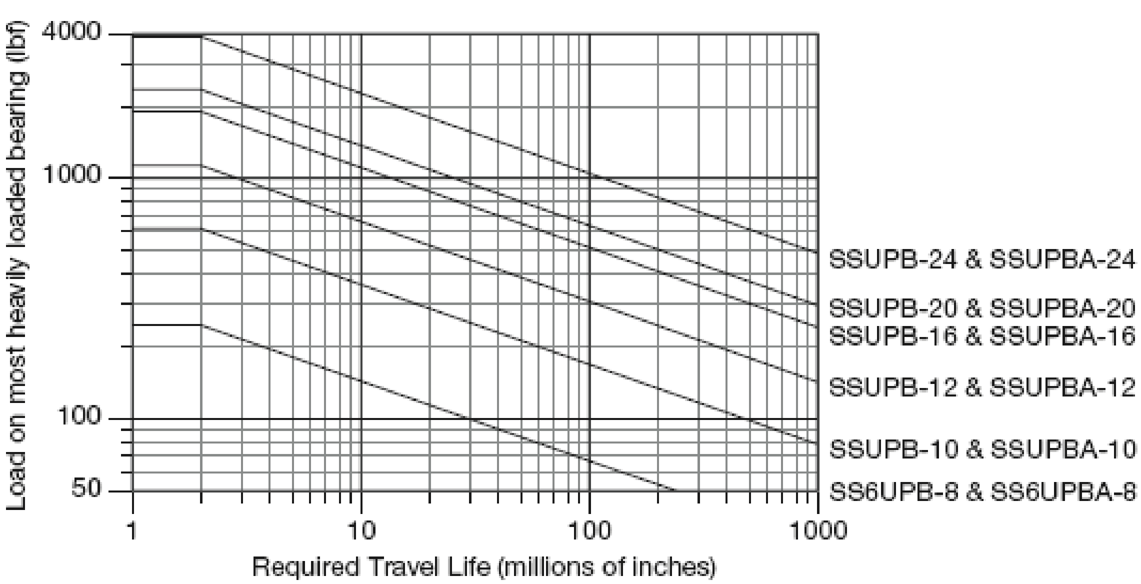
The principal advantage of the square rail over the round rail is its high positioning accuracy. The square rail has an order of magnitude higher accuracy than the round rail, a property that is especially useful for milling and grinding applications. It holds from 0.0002 to 0.001-in. over a length of 10 ft, compared to 0.01 in. for round rails. And it can handle this precision for a moment load; a single carriage and single rail is better suited for this than a round rail. And because the square rail handles higher loads at high accuracy, most users tolerate somewhat less smoothness than the round rails offer.

Although a single profile rail unit can handle a moment load, it's not always recommended. Two or more units should be used to balance the load or distribute the weight more uniformly, but one square rail may be used frequently where two round rails would be required. Moreover, the profile rail is easier to use from the standpoint of only needing one or two parts for a complete system, basically, the rail and the carriage, whereas the round rail comprises a few more parts.

The square rail has higher load-life capacity, defined as the amount of load it survives traveling a specified distance. For example, a 20,000-N capacity is based on a 100-km rating. And wear is minimal because it doesn't slide; it has rolling contact. Square rail life primarily depends on the type of environment in which it resides, and proper lubrication and maintenance. With all else being equal, however, the round rail is a little more tolerant because it is not as tight a package and not as sensitive to slight variations. A square rail is more sensitive to debris and an impact, although it does have a higher capacity and resistance to impacts when the impact doesn't affect the rolling element.

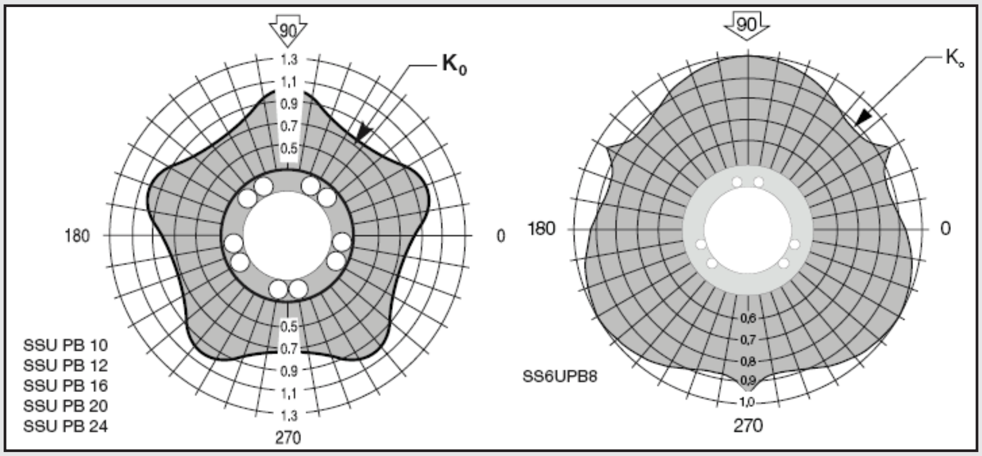
Round Rail Load/Life

Enter the chart with the maximum load of the most heavily loaded bearing and the required travel life. Find where the two lines intersect: The area through or above and to the right of the intersection indicates the bearings that are most suitable for the application.



Ball Bushing Bearing Polar Graph

The orientation of the bearing or direction of applied load determines the dynamic load capacity of a ball bushing bearing. The correction factor is found from the direction of the applied load relative to the orientation of the bearing ball tracks shown in the polar graph. To determine the load capacity, multiply the correction factor K by the dynamic load capacity of the specific unit.



Considering the wear aspect, the round rail also has natural debris-shedding capabilities. The square rail tracks are hidden somewhat from direct access, but do not necessarily shed the debris. When a gelatinous fluid driving force goes onto the rail, a round rail performs better than a square rail, because the square rail could pull up on some of the race areas, whereas the round rail has fewer tendencies for pull-up.

General Guidelines

Select a type of rail to use before starting the machine component layout. The mounting fixtures are radically different between round and square rails, and the area in which to work varies as does the load ratings for the physical size. If it doesn't work out later, changing from one brand of square rail to another brand is easier than changing from square rail to round rail of either the same brand or different brands. All manufacturers follow standards that allow some degree of interchangeability within a type.

Efficiency can be approached from two angles. One deals with the drag coefficient or friction; less friction means lower input energy. Round rail drag is a little lower and its action smoother than a profile rail. But those who use square rails regularly provide enough power to drive the rails sufficiently well. Some also consider efficiency from the standpoint of overall envelope or size. The smaller profile rail offers a smaller package for higher loads.

Shock loading, such as an instantaneous impact load, happens in every case, and all bearings are sensitive to it. The affect varies depending on the way the product is used. Square rails can handle a heavier load than a small unit, so shock is more of an impact force, but in all cases, the rail is scaled to the capacity of the normal load, not a shock load. There is no significant difference except that in heavy machinery a shock is more detrimental just because of the pure mass.

Deratings

Square rails come with some critical environmental deratings, typically found in the manufacturer's handbook or design guide. Unfortunately, derating factors are not considered frequently enough in the beginning design stages for either round or square rails. For example, the standard duty-cycle rating in the US is 2 million inches or 50 km and 100 km or 4 million inches for the European market. Very often, the standards recommend that a rail system not be used beyond either 25 or 50% of the rated capacity.

Misapplications

Most applications are borderline, that is, either round or square rails may be used when the installation is correctly prepared. But some rails are replaced with the other type because the former doesn't work. Such was the case in a hospital patient bed where the designer started with a square rail for axial movement. But, the assembly would bind; it couldn't move freely unless the mounting bolds were loosened to allow some twisting motion. The bed frame simply was not rigid enough. The square rail had to be replaced with the self-aligning round rail.

Another application suffering the same type problem was a square rail mounted to a sheet-metal base in a vending machine. The rail did not work because the sheet metal mounting was not rigid enough. Sometimes, designers repeat mistakes when they look at the same problem in a different light. When an engineer is familiar with round rails he may tend to stick with them, regardless of the application needs for higher accuracy. But most applications don't need the square rail accuracy. They should look at the entire system cost, not just the component cost. And that means incorporating the requirements for all the peripherals and extended issues.