

Drive & Control profile

The X's and O's of linear guide design



Linear guides house recirculating ball or roller bearings in a runner block mounted on a profiled rail. Some linear guides have multi-part seals to keep lubrication in and contaminants out.

How bearing construction affects moment and load capacity.

Linear rail and runner block systems have become the guidance method of choice for most every application requiring precise linear motion. They offer high load capacity and rigidity, low friction, and quiet operation, giving designers high performance in a compact package.

The linear guides consist of recirculating ball or roller bearings mounted on a profiled rail, and the low-friction rolling elements efficiently carry loads. They're generally

straightforward to specify, install, and maintain, and come in a variety of standard offerings. Rail and block systems typically range in size from 35 mm for most standard machines to 125 mm for large machine tools and equipment moving heavy loads. Smaller sizes are available for light-duty applications.

And, unlike sliding-friction guides such as traditional boxways—once the standard on many high-end machine tools—rail-and-block linear guides

Bearing construction considerations

- The bearing housing, rows of balls or rollers, and contact angles set the foundation for a machine's ability to support loads
- Moment loads magnify and concentrate contact stresses in the guide rail and runner blocks
- How a guide assembly reacts to applied forces and moments is critical in determining which type of guide to use. X and O designs differ in the way they disperse these reactions.

X and O linear guide arrangements

- The X arrangement has a face-to-face mounting geometry, resulting in a narrow footprint between the center lines
- The O arrangement has a back-to-back mounting geometry, offering greater leverage against the supporting rail, and resulting in higher rigidity and moment-carrying capacity

do not require complex lubrication systems. As a result, engineers have come to prefer recirculating, antifriction bearings for guided motion in demanding applications. For instance, they're often used on lathes, machining centers, grinding equipment, and other machine tools.

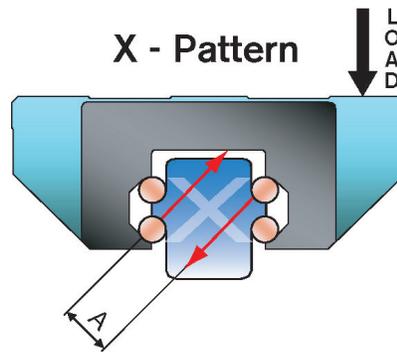
X versus O design

In metal-cutting, woodworking, and stone-cutting machines, linear guides are an integral part of the machine structure and can significantly contribute to overall performance. Precision often differentiates one machine from another, creating a competitive advantage for machine builders and, in turn, users. With any luck, these advantages also translate into higher profits, better quality, and more satisfied customers for both companies.

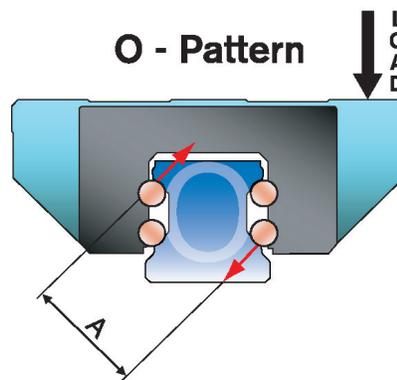
As a result, a linear guide's travel smoothness and tolerance variations are key concerns for machine designers. But, arguably, the most important design factor is how well the guide resists deflection. With high acceleration rates and ever-increasing cutting forces, linear guides must be the anchor for tool-point accuracy.

But not all linear guides offer the same degree of deflection resistance and, thus, precision. So how does one rail and runner block style differ from another? The answer lies in something as obscure as the orientation of balls or rollers inside the block as it slides along the rail.

Several rows of balls or rollers inside the bearing housing typically create a face-to-face or back-to-back arrangement in the angle of contact to the rail. Mounting geometries are



X-style rolling elements inside the bearing housing result in a narrow footprint between the center lines (Dimension A) of load-absorbing balls. This reduces the guide's ability to handle moment loads.



An O-style rolling element has a wider stance between the balls and greater resistance to applied moment loads than X-style elements.

also termed X (face-to-face) and O (back-to-back).

The X and O terminology stems from the graphical representation of forces in the bearing and rail. In the X arrangement, balls or rollers contact the rail in an inward-facing fashion, creating a crossing pattern inside the rail. For the O configuration, the lines cross outside the housing due to an outward facing ball-track orientation. For a given size, the O arrangement's wider stance creates greater leverage

against the support rail, giving the linear guide more rigidity and moment-carrying capacity compared with an X design.

Accompanying graphics compare the two designs and show how lines of force act within the rail supports. Moment reactions within the bearing must equal the moment arm of the applied load. An O arrangement, compared to the X arrangement, provides wider spacing for the forces—thus generating better leverage and, consequently, better dispersal of moment-based forces.

The two versions are also sometimes referred to as "Asian" versus "European" block designs because of the differences among several prominent guide manufacturers. In fact, both configurations are commonly used by linear-guide manufacturers from various parts of the world and have nothing to do with regional or national preferences. What's important is that the bearing housing, rows of balls or rollers, and contact angles set the foundation for a machine's ability to support loads.

How a guide assembly reacts to applied forces and moments is critical in determining which type of guide to use. In most cases, a combination of direct and moment loads act on linear-guide assemblies. Direct forces are fairly easy to handle. Moment loads, often overlooked, are not as clean and simple, plus they magnify and concentrate contact stresses in the guide rail and runner blocks.

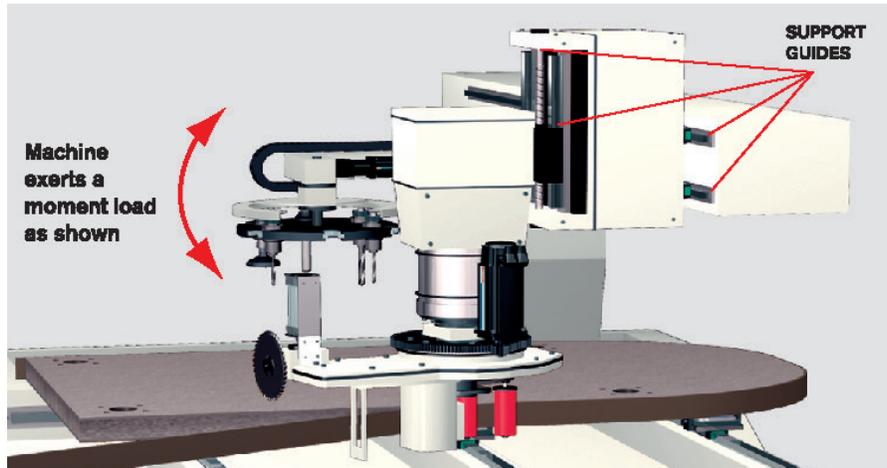
X and O designs differ in the way they disperse these reactions. A good analogy might be found in a football player choosing a four-point

versus a three-point stance. The wider overall arrangement of anchor points distributes forces more evenly, providing better resistance to offset or uneven loads.

Heavy-duty applications

Engineers, when faced with this design choice, must also consider the machine configuration. Complex machines such as large gantries and five-axis machining centers have large masses that are typically overhung or suspended from the structure. They induce a variety of moment loads on all axes of motion, further compounded by high acceleration rates. Even small machines with high dynamic requirements can create extremely demanding environments.

Complex machines rely heavily on their structures to maintain accuracy and performance. Many manufacturers even go so far as to tune a machine's structural frequencies by filling voids and adding polymer or granite structural members in key areas. Such measures increase rigidity and counter the negative effects of phenomena



The high speeds and complex tools used in many modern machine tools, such as this woodworking machine with a heavy offset load, place high demands on linear guides.

such as settling time, resonance, and deflection.

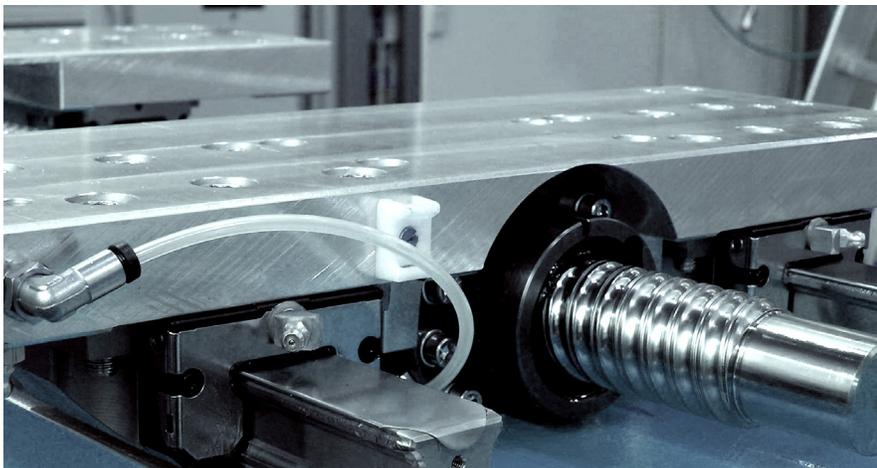
As discussed earlier, engineers should factor the guide into the overall design. In the example machine shown, the guide arrangement permits loads in all directions, moments about all axes of travel, and high dynamic movements over long travel lengths. The designer would have to consider dynamic capacity of the supports, as well as moment capacity in each

axis. When properly designed, O-type guides have equal dynamic capacity in all directions (normal loads, lift off loads, and side loads). They also optimize moment capacities, letting designers position the rail and bearing structure in a number of different ways. Horizontal, vertical, wall-mounted, and upside-down configurations are all possible with O guides.

Light-duty and direct loads

On the other hand, not every machine is quite so elaborate. Some only require a single axis of horizontal travel. Others may have simple movements, such as full-stroke, back-and-forth operation. In these instances loads are basic. Linear guides may need to support only the tool weight, with neither moment loads nor heavy acceleration forces.

Designers must, however, understand whether the application needs precise repeatability, quiet operation, or simply moving from point A to B. A simpler arrangement does not necessarily mean less need for accuracy or capacity.



Many less-demanding applications require controlled motion. A number of light-duty linear guides address such needs, including designs with only one row of bearings on each side of the rail.

Typical features common to both X and O arrangements include various precision classes, physical sizes, and mounting features such as bolt-hole spacing along the rail. Travel accuracy and repeatability are generally comparable in either X or O-type guides if other factors, such as precision class, are the same. If load orientation happens to be in an agreeable direction, life calculations are comparable as well.

Many machines can truly be considered light duty but still need controlled motion. Applications such as a packaging pick-and-place, and woodworking routing adjustment and hard stops typically have only general tolerance requirements. A number of products can address such applications, including designs with only two rows of bearings, one on each side of the rail. Miniature products typically have only two rows

as well. And other light-duty designs on the market specifically address the needs of these machines.

X or O?

So what conclusions should a machine designer draw from this discussion of X versus O bearing design?

First, it is valuable knowing that bearing designs differ. Marketers of linear guides often point out other small differences in their systems (ball spacers, lubrication concepts, and so on), so it's certainly worth knowing that the bearing arrangement inside the housing affects machine performance.

Second, a linear guide is just one element in a machine, although it's critical in terms of ultimate performance. In machines that guide heavy tools through metal or stone to produce a finely machined edge,

O-style bearings may reduce the need to add rigidity elsewhere in the machine. They may also extend the machine's overall life and reduce maintenance. And because O-style bearings generally cost the same as X-style ones, it might be worth insisting on an O-style design.

Of course, in the final analysis, designers must determine whether an X or O arrangement is even a factor. High-performance linear guides are overkill for many light-duty machines and light-duty applications such as sliding doors in heavier machines.

The bottom line? The X versus O discussion is one more item to consider, along with ball spacers, lubrication, and other bearing design details. Finally, it's important to work with guide suppliers to determine the right bearing and arrangement for an application.

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