The long and short of linear bushings

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Linear bushings take on a variety of load-carrying tasks and don't ask for much in return. All they want is a fair fight, to be matched with the application at hand.

If you've ever found yourself strapped to a pair of cross-country skis, then you already understand how gliding platforms of length can augment linear motion.

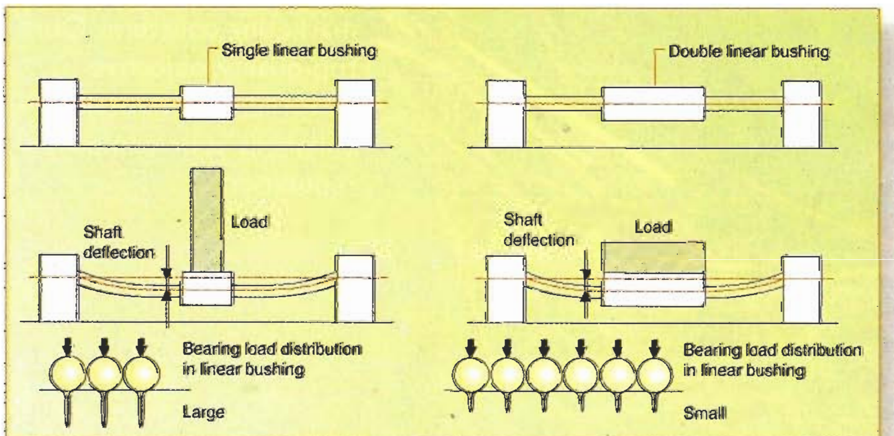
Linear bushings are what many motion systems ride: They're inexpensive, well balanced, and make for effective linear guides. They also work well with different actuator types and in various configurations, having a small coefficient of friction and an ability to compensate for construction-related imperfections.

Selecting a linear bushing for a particular application requires an understanding of how they're built and how they work. It also requires some thought with regard to material properties, surface treatments, and application environment. Get these things right and linear bushings will turn in a solid performance, dependably moving their load for as long as they're properly maintained.

Length type

Linear bushings come in several varieties. The linear bushing design we discuss here is the hollow cylindrical element containing several tracks filled with steel balls that recirculate as the unit rides along its shaft. Standard linear bushing length types include single, double, long, and custom — which is usually composed of two single-length units.

Length type is an important design consideration because of its influence on two key bearing performance parameters, namely load resistance and guidance accuracy. Load resistance is the maximum allowable load a bearing can safely support; guidance accuracy is a measure of precision with which a linear bearing translates its load.



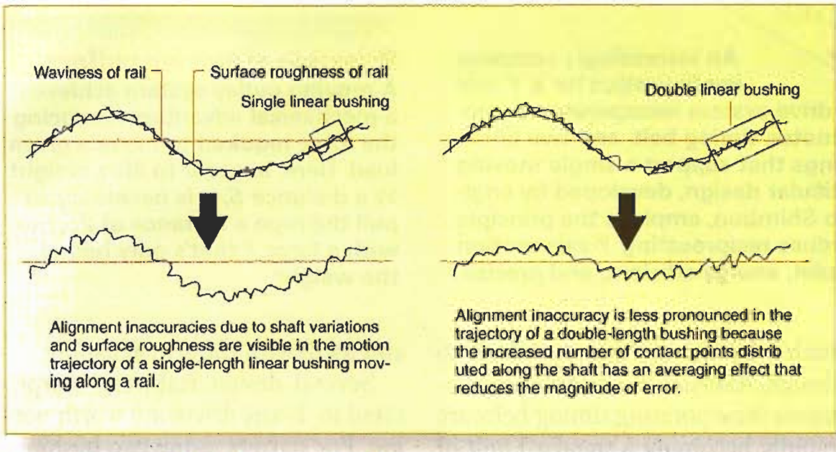
How bearing length determines allowable load

Adding to the length of a linear bearing with evenly spaced balls means more points of contact over which to distribute a given load. More balls sharing the load means proportionally less load force on each ball, which translates to longer bearing life, less wear, and greater reliability.

Load resistance

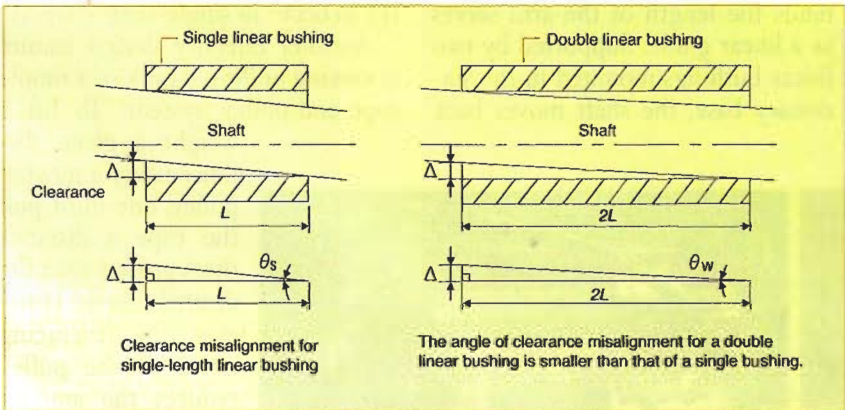
The relationship between length type and load resistance is based on bearing construction. For a given ball spacing, the longer the bearing unit, the more balls it incorporates. As a result, whenever bearing length is increased, the load it's intended to carry is distributed over more balls, proportionally reducing the load on each point of contact. Naturally then, the longer the linear bushing, the greater the load it will support.

From a design standpoint, us-



Factoring out shaft irregularities

All linear shafts possess a certain amount of dimensional error in the form of waviness and surface roughness. Misalignment caused by this depends, in part, on bushing length. The longer the bushing, meaning the more balls contacting the rail, the less impact dimensional irregularities have on misalignment.



Clearing clearance error

The clearance required between a bearing and its shaft is a potential source of misalignment error. This error depends on bearing length. For a given amount of clearance, the longer the bearing, the correspondingly smaller the angle of misalignment.

ing longer linear bushings increases maximum allowable load. In a more practical sense, for a given application, an increase in bushing length equates to longer bearing life and improved reliability.

Guidance accuracy

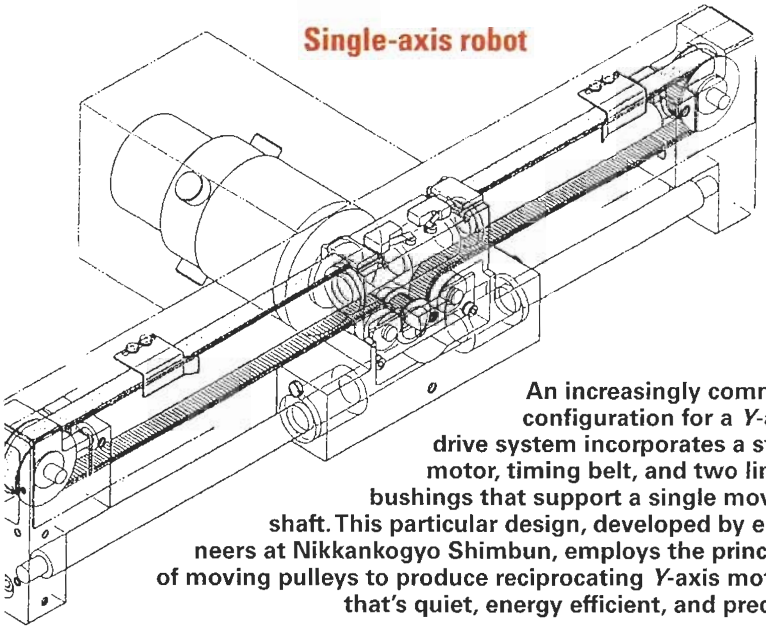
Like load ratings, guidance accuracy also improves with increasing bearing length. One reason for this is that guidance misalignment due to shaft irregularities (variations in straightness and surface finish) is neither a cumulative nor local property. Rather, it's an effect, the magnitude of which is averaged over the length of the bushing. For a given level of dimensional shaft error, the longer the bushing, the less effect irregularities will have on overall bearing alignment.

Another reason guidance accuracy improves with bushing length has to do with clearance misalignment — alignment error caused by the clearance between the bearing and shaft. From simple geometry, the shorter the bearing and corresponding shaft length, the greater the angle of potential misalignment inherent in the looseness required for clearance. Conversely, the longer the bearing, the smaller the misalignment angle formed in the clearance between the bushing and shaft.

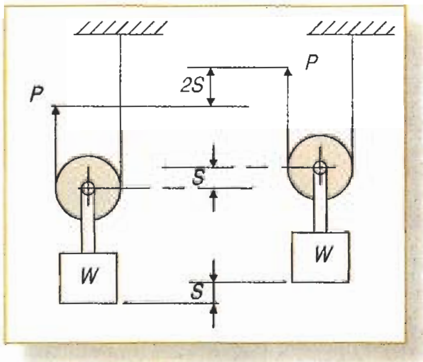
Linear bushings at work

To get a better handle on how to most effectively employ linear bushings it is necessary to consider them in the context of different applications. Linear bushings are incredibly versatile and can be configured with many other components in numerous ways. In today's automation environment, however, a growing number of applications involving bushings include stepmotors and either belt or ballscrew-driven carriage or stage assemblies.

In linear motion applications,



An increasingly common configuration for a *Y*-axis drive system incorporates a stepmotor, timing belt, and two linear bushings that support a single moving shaft. This particular design, developed by engineers at Nikkankogyo Shimbun, employs the principle of moving pulleys to produce reciprocating *Y*-axis motion that's quiet, energy efficient, and precise.



Principle of moving pulleys

A moving pulley system achieves a mechanical advantage, reducing the force required to move a given load. Here, in order to lift a weight *W* a distance *S*, it is necessary to pull the rope a distance of *2S*, but with a force *F* that's only half of the weight.

timing belts match up particularly well with stepmotors, efficiently converting rotary shaft output to linear position. Timing belts operate quietly, weigh next to nothing, and are relatively inexpensive. They also need no lubrication.

In a typical two-axis *X-Y* positioning system, where it's necessary to reduce the weight of the *Y* axis and minimize the load on the *X*-axis motor, a timing belt is ideal, meeting weight requirements while achieving a fair amount of precision. In fact, fueled by the systems approach to design, modular *Y*-axis drive mechanisms incorporating timing belts are rapidly becoming a standard unit of automation, approaching plug-and-play status.

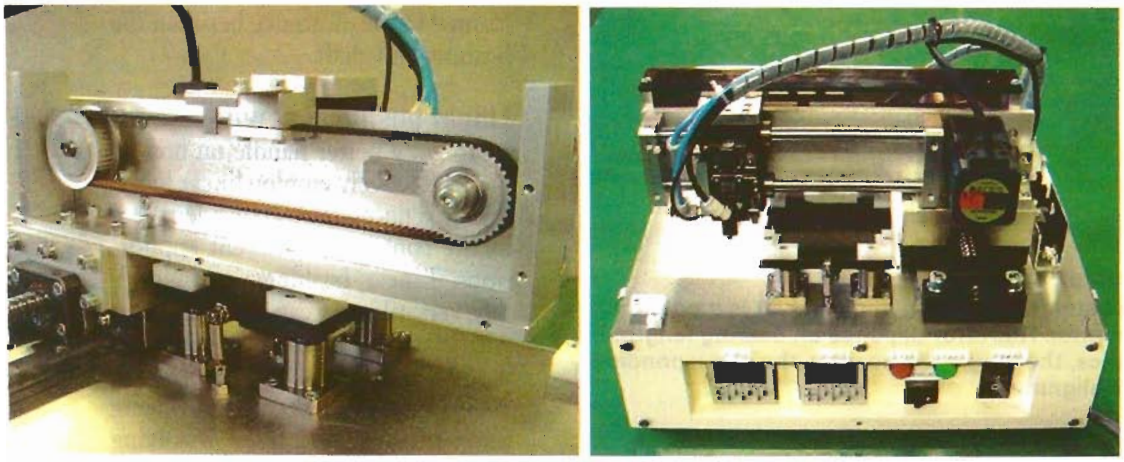
The moving element, or carriage, in a typical *Y*-axis drive is essentially an arm orthogonally mounted with respect to the base. A shaft that extends the length of the arm serves as a linear guide. Supported by two linear bushings mounted in the stationary base, the shaft moves back and forth with the arm assembly.

Several design features incorporated in *Y*-axis drives are worth noting. For starters, using two bushings increases load allowance, and the separation between them helps improve alignment and precision.

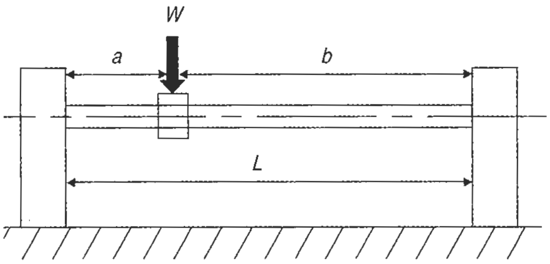
Because the timing belt is parallel to (and above) the shaft, it prevents the harmful bushing rotation that's apt to occur in single-shaft systems.

Another effective design feature is moving pulleys. Think of a simple rope-and-pulley system: To lift a weight a given distance using a moving pulley, one must pull the rope a distance that's greater than the desired move. However, the leveraging effect of the pulley reduces the amount of force required to lift the weight by an amount proportional to the pulley radius.

All moving pulleys improve precision because they amplify the resulting motion for a given input. On a motor-driven linear axis,



An automated transfer system employed in semiconductor manufacturing relies on a timing belt to drive its *Y* axis. The carriage (viewed from the front on the right) moves along two linear rails, riding smoothly on linear bushings.



Deflection formula

$\partial = W \cdot a^3 \cdot b^3 / 3 \cdot E \cdot I \cdot L^3$

a = Distance support to load point

b = Distance opposite support to load point

L = Distance between shaft supports

E = Young's modulus

I = Shaft's geometric moment of inertia

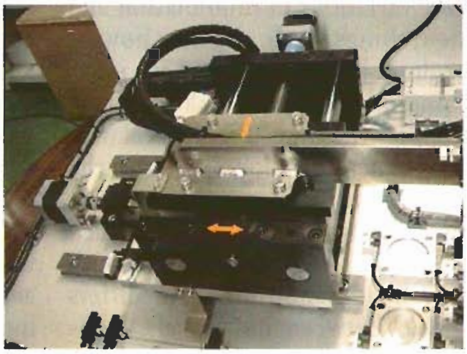
$I = \pi r^4/64$, where r = shaft radius

Calculating shaft deflection

Loads carried by linear bushings cause a certain amount of shaft deflection that can be calculated using a fairly straightforward formula. Two options for reducing deflection include using a larger diameter shaft and shortening the distance between supports.

this translates to greater positioning accuracy for a given shaft resolution. The multiplier also reduces the amount of backlash or lost motion imposed by the pulley itself.

Pulleys do require that motors run faster, but this is actually helpful because stepmotors are most efficient at higher speeds. Also, systems that include pulleys (and their mechanical advantages) can operate with smaller (less expensive) motors.



Stepmotor-propelled ballscrews drive both the *X* and *Y* axes on this heavy duty positioning table. Linear bushings carry the moving assemblies on solid steel shafts, supporting large loads while optimizing speed and precision.

Bushings with a twist: Ballscrews

Linear drives incorporating stepmotors and ballscrews are also becoming more common in motion-centric automation. Ballscrews convert stepping increments directly to linear movements. What's more, their pitch functions like a reduction gear. These two qualities combine to make stepper-based ballscrew drives efficient as well as powerful, excelling wherever high force transmission is required.

Ballscrew drives also benefit from the fact that stepmotors can generate large amounts of torque at low rotational speeds. This is particularly advantageous during the acceleration (startup) and deceleration phases in point-to-point positioning applications. It's also beneficial when moving short distances, as in indexing cycles, and in applications involving multiple positioning intervals.

For more information on linear bushings, call a Misumi applications specialist at (800) 681-7475 or visit Misumi's website at misumiusa.com. E-mail inquiries may be sent to inquire@misumiusa.com.