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Misconceptions can lead to overspending and premature failure.

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With so many different ball screws on the market and the attendant flood of data from manufacturers, designers can have a tough time sorting out what truly affects ball-screw performance. Information often focuses on whiz-bang features that bring few real benefits, while more mundane but critical factors are missed completely.

To help cut through the confusion, here’s a look at four factors critical to successful ball-screw applications, as well as some related myths and misconceptions.

**TRAVEL ACCURACY**

Typically, an engineer’s first and foremost concern is travel accuracy, which is possibly why so many standards address this single topic. Chief among them are DIN 69051, ISO 3408, JIS B1191, and ANSI-B5.48, which cover topics ranging from material specifications to geometric tolerances.

The different norms can confuse the important issues. But common to all the specs is that lead error is the most critical indicator of travel accuracy. Lead error refers to the travel error over a given length as the nut travels along a screw. It is expressed in “mm per 300 mm” or “inches per foot” and determines a ball screw’s accuracy rating.

According to convention, a lower rating number means less lead error and, therefore, better accuracy. In other words, a Class 1 screw has a substantially higher accuracy than a Class 7 screw. Of course, the high-accuracy Class 1 screw also costs more and may take up to 10 weeks longer to produce. Designers should use accuracy ratings as the starting point for overall slide accuracy, but also weigh performance requirements against lead time and cost.

**Myth #1: Accuracy dictates the manufacturing method.**

This implies high-accuracy screws must be ground, not rolled. In fact, although many designers believe grinding is the only way to make high-accuracy screws, no specification dictates a production method for a given ball-screw class. The specs do, however, differentiate between “Precision” and “Transport” screws. Although lead error represents millimeters of error per 300-mm travel segment, T-Class lead error can accumulate over multiple segments. In contrast, P-Class accuracy controls 300-mm lead error and limits accumulation over extended lengths.

In the past, rolled or cold-formed screws traditionally fell into the T-Class arena, and only ground ball screws could hold P-Class tolerances. Today, however, technological advances let some manufacturers produce P-Class accuracies in precision-rolled screws. Rolling has evolved into a CNC-controlled, tight-tolerance process capable of P3 accuracy, near-perfect roundness, and tolerances well within DIN control limits.

The capability to produce screws of most any accuracy with either technique...
offers significant benefits. Machine builders no longer have to pay premium prices for top performance and tolerate excessive lead times. This lets them offer superior machines at a better price, while still making a fair profit.

**NONScrew FACTORS**

In selecting components for a given application, designers must also consider factors beyond the ball screw itself, such as accuracy and repeatability.

**Myth #2: Ball-screw accuracy equals axis accuracy.**

On the surface, this seems true. But, accuracy and repeatability are not the same, and other machine components affect the total tolerance stack-up. Repeatability is the screw’s ability to return to a defined point, time after time, and most designers agree it is most critical.

Many factors contribute to repeatability, including drive connections, guide mechanisms such as rails or shafting, and the machine structure itself. It seems logical that poor performance of surrounding components can jeopardize both the accuracy and repeatability of even a “perfect” ball screw. Yet the pressure to cut corners and save money often results in less than satisfactory machine performance once testing begins. Then, the need to redesign a machine negates any short-term savings, delays market introduction, and may add to maintenance or repair costs for end users.

Assuming the machine structure has been properly designed, one can concentrate on motion-related components. To optimize performance, eliminating any and all lost motion — commonly referred to as backlash — is critical. Typically, most backlash is between the ball nut and screw, and a range of nut designs helps remove backlash by preloading the system. Preloaded ball nuts have neither axial nor radial freedom. Instead, the ball nut is matched to the screw by adjusting a variable dimension. This can be accomplished in several ways.

One preloading method uses a double-nut system. Double nuts wedge the nut bodies together against a spacer and lock them in place. (A simpler example of this would be a “jam nut” used on a nut-and-bolt mount. The second nut wedges against the first and locks it in place.)

Another preloading option is the lead-shift method. It uses a manufactured off-set in the raceway spiral, shifting it a few microns halfway down the nut. This changes the angle of engagement for the balls in a similar fashion to the double nut.

Finally, the ball-select method uses balls that are intentionally a few microns larger than a perfect fit. Because the balls are larger than the groove, they are forced into contact with all raceways of the nut and screw. This four-point contact eliminates backlash. But only a few manufacturers can hold the tight tolerances that both nut and screw require in the ball-select method.

**Myth #3: The double nut is the best preloading method.**

While the double nut provides excellent preloading, for many applications a ball-select preload offers almost the same performance at considerably lower cost. A common misconception about the double-nut method is that two nut bodies will double load capacity. In fact, each nut body takes load only in one direction. The opposing nut actually deflects out of load sharing during operation so capacity does not double. Double nuts are also difficult to assemble.

Lead-shift nuts have ball-contact patterns similar to double nuts but typically have fewer active grooves. This reduces load-carrying capacity and, therefore, life expectancy.

Ball-select preload strikes a compromise between these two options. Oversized balls make each groove in the nut an active one and take loads in both directions.

Another lost-motion consideration is deflection. The *System rigidity* chart compares a double nut, lead-shift nut, and ball-select nut, all on screws of increasing length. The double nut has only 5 to 10% higher rigidity versus the ball-select nut, while the lead-shift version drops off dramatically. Taking the effects of screw length into consideration, as shown in the chart, the ball-nut styles have even less differentiation. Thus, in many applications, a single nut with ball-select preloading offers much the same performance as double nuts, at substantially lower costs.

**LUBRICATION**

Even a well-designed ball-screw assembly that meets an application’s performance specs may disappoint in real-world operation, and lubrication failure is the number-one cause of premature breakdown.

### Comparing preload options

<table>
<thead>
<tr>
<th>STYLE</th>
<th>DOUBLE NUT</th>
<th>LEAD SHIFT</th>
<th>BALL SELECT</th>
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<tbody>
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<tr>
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A brief comparison shows key advantages and disadvantages of different preloading methods.
**MYTH #4: Lubed-for-life screw assemblies guarantee 10,000 km of travel.**

One common misconception, supported inadvertently by many manufacturers’ claims, is that “lubed for life” means exactly that: No maintenance is ever required.

Many publish test data on systems that produced 10,000 km of travel. But for users, it is critical to know the test conditions and how they relate to real-world operation. In some cases, 10,000-km results are measured with no applied loads in clean-room environments.

Real-world applications rarely run clean and unloaded. For a ball screw operating inside a machine tool, with heavy loads and high speeds, lubed-for-life claims are dubious at best.

It’s important to understand how a manufacturer’s claims relate to an application. If test conditions are not easily understood, or if the claims seem too good to be true, get more information to avoid disappointment in the end.

When comparing products from different suppliers, always try to get enough data for an “apples-to-apples” comparison. So-called “lubed-for-life” designs do extend service intervals because they seal in and maintain lubrication where it is needed, inside the ball nut. Effective seals also keep out contaminants. But “life” means different things to different manufacturers.

In the end, the most important point is to find the best match of capabilities, price, and lead times for the application. Usually, machine design and component choices determine how to get the highest performance with the lowest total cost of ownership. Mistakes can be costly, either in redesign losses or, more importantly, poor machine performance.

These four factors are the most critical, but other considerations can play a role as well. They include end-support bearings, overall system rigidity, and operating environment, just to name a few.

All potentially have a severe impact on screw performance and life. So it is always a good idea to review the application carefully with the screw supplier’s engineers. They may have seen similar applications and can help avoid mistakes others have already made. They’ll also help ensure the right ball-screw and ball-nut combination.

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**Preloading options**

This illustration shows 2D representations of different preload methods. In each, the diagonal lines represent the direction in which force is applied to the balls.

The double-nut method shows the lower edges of two nut housings separated by a spacer plate. The spacer plate applies force to the nut housings which, in turn, apply force to the balls in the screw shaft raceway.

In the lead shift method, the raceway in the nut body itself has a manufactured offset to apply force to the balls as the nut travels along the screw. (The offset is shown as “lead + a.”) In the ball-select method, the balls are slightly larger than the groove.