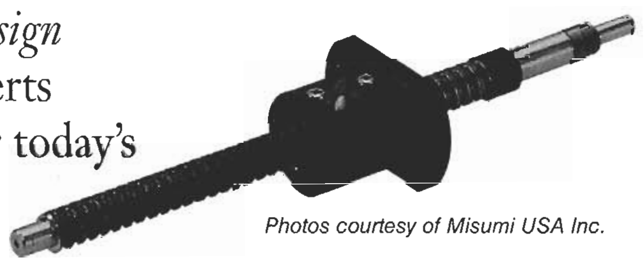
Ballscrews vs. lead screws

In this forum, *Motion System Design* editors speak with industry experts about the best screw choices for today's automation environment.



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HOW DOES THE CHOICE OF A BALLSCREW OR LEAD SCREW AFFECT PRODUCTIVITY IN A MOTION-CENTRIC AUTOMATION ENVIRONMENT?

Woody • THK: Ballscrew technology allows balls to roll between the screw shaft and the nut to achieve high efficiency, usually above 90%, depending on lead angle. Its required driving torque is only one third of a conventional lead screw. As a result, ballscrews are capable of converting rotational motion to straight motion and vice versa. This screw type is suitable when smooth motion, efficiency, accuracy, and precision are a priority. The rolling elements eliminate sliding friction, so smaller motors can be used to drive ballscrews. And, because rolling motion is easier to control, accuracy and precision are also easier.

Lead screws are different in that there are no recirculating elements, and they are often used for simple transfer applications when speed, accuracy, precision, and rigidity are not as critical. On a positive note, more surface contact of the threads can make for a higher load rating of the nut over ballscrews. However, their metal-to-metal contact and high friction makes lead screws more suited to applications that do not require prolonged continuous movement or high speed.

Tom • Kerk: Productivity is a result of both throughput while equipment is running and overall utilization rate. Screw selection affects both. A well-specified screw provides quick, efficient motion with the capability for a high duty cycle, "on the fly" operation, and a compact layout, which enables higher density operations. High quality precision lead screws have the additional advantage of being exceptionally quiet and vibration-free. So, they're acceptable in non-traditional locations: On medical lab equipment in doctors' offices, in desktop CD/DVD duplication devices, and in many new rapid-prototyping technologies.

Gary • Tolomatic: Ballscrews and lead screws are the workhorses of today's motion-centric automation environment. In that light, making the correct choice for an application is extremely important. It's all about understanding the application and what is to be accomplished: For example, required speed, thrust, backlash, lead accuracy, efficiency, and back-driving tendencies all must be understood and considered. Beyond these mechanical issues come the less tangible issues such as noise, lubrication requirements, and intended or useful life in the application.

WHAT ARE THE MAIN CHALLENGES REGARDING WORKING WITH BALLSCREWS AND LEAD SCREWS?

Paul • Misumi: Keep four factors in mind to select the right screw mechanism for the job:

Proper load calculation. Most of the time, applications are either over or under-engineered, which can cause screw failure (if under-engineered) or too costly a screw (if over-engineered).

Properly attached load size. Misalignment of an attached load can create unexpected side loads and moments; if more than one screw is used, an uneven load may be created, which can also shorten screw life.

Correct lubrication intervals. Maintaining optimal lubrication is essential to getting the most out of ballscrews and lead screws.

Accuracy and cost tradeoffs. Ballscrews usually offer higher accuracy than lead screws, but for less demanding applications, it's not necessary to use the more expensive ballscrew technology.

John • Exlar: Typically, application requirements dictate the type of screw that can be used. Ballscrews, while they offer high efficiency, are not self-locking, nor are they as rigid as a lead screw (or Acme screw). Lead screws are typically self-locking, which can eliminate the need for additional brakes in the system to support, for example, a vertical load during power loss. And they typically offer high rigidity. But, lead screws are very inefficient, and limited in both rotational speed and duty cycle as a result.

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Neither component offers the best of all worlds, and so most designs using screws involve compromise. For example, a user might like to have a screw that can offer a 100% duty cycle at high speed, but would prefer it to be self-locking and not need a brake. Or, a user might prefer the load capacity of an Acme screw in the same size as a ballscrew, but can't achieve it.

Woody • THK: Ballscrews and lead screws are only able to take on axial loads; any misalignment causes moment/radial loads on the shaft. If these factors are not considered, several types of premature failure may occur. Lead screws are not for micro-feeding applications, and are very hard to preload to increase rigidity. And, because there are no recirculating elements, lead screws are more likely to bind if contaminants enter the nut.

Tom • Kerk: The greatest challenge is using specifications to predict functional performance. Most specifications relate to theoretical operation or laboratory performance. Real-world performance is often significantly different because of manufacturing tolerances, environmental variations, lack of maintenance, and normal degradation from wear and tear. These losses are very hard to predict. The picture is further clouded by a lack of standards for reporting specifications and performance. We have found there is no substitute for testing in the application. One caveat: Especially with screws, accelerated testing rarely produces valid results. Increased speeds, accelerations, loads, and duty cycles often produce premature failure because the limiting characteristics of screws are not linearly proportional to operating parameters.

Used within their design parameters, lead screws offer longer life, lower cost, less noise and vibration, a wider range of leads, and more design flexibility. On the other hand, ballscrews have higher maximum load bearing capability. The difference between sliding motion and rolling motion has a distinct impact: Think of a table with a ball bearing and a square block of material sitting on top; slightly lifting one side of the table will cause the ball bearing to roll, but the block will not slide until the table is lifted enough to overcome the friction between the block and the table. This demonstrates the efficiency differences between lead screws and ballscrews.

Ballscrews offer high efficiency, even with small leads, and will back drive. In contrast, lead screw efficiency depends on the lead and material, so designers can control whether the screw will back drive. For vertical motion, lead screws can be self-locking so that even without brakes, dropping or drifting when motor power is removed or lost can be prevented. But the higher friction of a non-backdriving screw requires increased power to drive.

Gary • Tolomatic: Understanding the application requirements remains the main challenge in applying these devices. For example, a precision-ground ballscrew may be an excellent choice for equipment requiring very precise or accurate motion. However, costs associated with a ground ballscrew may not be economically justifiable for general-purpose motion requirements. A better choice in this case may be a precision rolled ballscrew, which likely has similar mechanical performance characteristics but lacks the precision lead accuracy. Conversely, a lead screw with a solid or polymer nut may be an excellent choice when application parameters require infrequent motion or near silent operation, but not a good choice when high duty cycles or linear forces are required.

WHAT NEW OPPORTUNITIES EMERGE AS BALLSCREWS AND LEAD SCREWS BECOME MORE TECHNICALLY ADVANCED?

Woody • THK: Ballscrews with caged technology will achieve higher DN (rotational speed of nut) values due to the continuous development of cage technology and nut return methods. Caged technology eliminates ball-to-ball contact, thus lessening the total area of metal-to-metal contact and reducing particle generation from ball-to-ball contact. Caged technology even forms a grease pocket film around balls so that lubrication and maintenance intervals are significantly extended.

Tom • Kerk: Miniaturization has opened up many new opportunities in personal insulin pumps, auto-focusing optics and photonics, and desktop automation. Increased precision has enabled advances in semiconductor manufacturing, higher density data storage systems, improved resolution for digital scanning and printing, and greater accuracy in automated guidance systems. New materials have allowed screws to be moved into non-industrial environments where maintenance is not acceptable. Medical and life science industries are the fastest growing markets for precision lead screws; the automotive industry is also expanding screw usage for quiet, efficient automation of many convenience options in current and upcoming models.

Gary • Tolomatic: Opportunities associated with increased levels of precision or lead accuracies due to manufacturing advances will drive costs down. This may very well mean that ballscrews and lead screws will be more widely used in automated systems. The advances underway related to motor and drive technology plays well with more technically advanced screws.

WHAT WILL TOMORROW'S BALLSCREWS AND LEAD SCREWS LOOK LIKE?

Paul • Misumi: Fast developing nanotechnology will create materials or coatings with much better properties (low friction and better wear) that will increase the life of ballscrews and lead screws required in demanding industries, such as aerospace, that have a high temperature, high humidity environment.

John • Exlar: One advancement that's been around since the 1940s, but has only begun to take hold in the last 10 to 15 years, is the planetary roller screw. This screw type combines some of the best features of the ballscrew and roller screw. The planetary roller screw is designed using threaded planetary rollers traveling around a threaded shaft, and inside a threaded nut. The advantages result from offering a higher amount of contact area than a ballscrew, but similar efficiency due to the use of the threaded rollers.

Compared to an Acme screw, planetary roller screws offer 100% duty cycle use, and high-speed operation, while still carrying very high loads and offering long life. Compared to a ballscrew, planetary roller screws offer significantly longer life, higher rigidity, less vibration, higher rotational speeds and accelerations, higher shock load resistance, and less derating because the planetary design eliminates the conflicting friction of the ball bearings within a ballscrew.

Tom • Kerk: Nonmetallic materials will create new opportunities. Precision plastic screws will enable integrated components with lower manufacturing costs and simplified mechanisms. Ceramics will also proliferate, extending life and allowing screws to be used in exceptional environments. Advanced manufacturing of high-lead screws will enable linear to rotary conversion. In the future, it will become more common to use a backdriving screw to create rotation by pushing the nut. This is a valuable approach for hand instruments without electrical power.

Jim • Tolomatic: Tomorrow's ballscrews and lead screws will offer extreme life, either achieved by lubrication delivery systems or metal surface treatment or metallurgy, with no sacrifice of quality or cost. Today, to achieve long life or higher loads, customers may choose planetary roller screws, which are very costly relative to lead screws. Achieving long life at near the same costs is a market need, and the supplier that figures this out (or designs an alternate force transmission system) will emerge with a big chunk of business. **MSD**