Which Screw is Best for You?

By: Travis Schneider
Selecting an actuator doesn’t need to be an art, when it’s a science.

In the world of electric linear actuators, screw drive trains are among the most popular for converting rotary to linear motion, but with so many options what’s right for you? Having a thorough understanding of each technology will allow you to properly select the ideal screw for your next motion application.

This is a cutaway image of Parker’s ETH 50 electric cylinder. The ETH series uses an optimized ballscrew as its drive train. This optimized ballscrew design gives the ETH thrust densities that rival fluid power actuators of similar size.
The Players

There are three major screw technologies. It is important to note that each technology has its benefits and drawbacks. Each screw acts as a force multiplication device, taking rotary torque input from a motor and converting it to linear thrust.

The Ballscrew

A majority of linear motion applications use ball screws to convert motor torque to linear thrust due primarily to their commercial availability, high efficiency, and load-life characteristics. Mechanically, the ball screw is composed of a metal screw and nut, which uses metal ball bearings as the mating interface between threads. There are several manufacturing techniques used to manufacture a ball screw; most popular are rolling, grinding, and whirling. Ball screws, if properly designed, are an ideal solution for industrial applications with high duty cycles which also require high thrust – similar to applications that one would typically use and air cylinder or even a hydraulic cylinder.

The Leadscrew

Lead screws are often the mechanical drive train of choice for applications requiring low precision, and low duty cycle for a low cost. Lead screws are composed of a metal screw which interfaces with a softer nut (often plastic or bronze). Primary manufacturing techniques are either rolling or grinding. Lead screws are not always an ideal technology for industrial applications given their wear characteristics, but are great for applications requiring low duty cycle adjustments to positions, or a self locking drivetrain.

The Rollerscrew

A roller screw is composed of a screw and interfacing nut just as in ball screws, but instead of ball bearings being the interface from nut to screw, small rollers rotate to provide contact between the nut and screw. This nut technology allows for line contact between rollers, nut, and screw – which makes this technology superior to ball screws when it comes to shock load and overall stiffness. Manufacturing techniques to produce these screws are quite costly due to the tight machining tolerances required, and for this reason screw lead times are quite long when compared to ball or lead screws. Roller screws often serve a particular niche, where an application requires a large load and extremely long life.

So which is the right technology for your application? Well... it depends. Most design engineers are quickly able to discern applications for which lead screws will or will not work. For that reason, the rest of this discussion will be focused on ball screws and roller screws.

<table>
<thead>
<tr>
<th>Screw Technology</th>
<th>Lead Screw</th>
<th>Ball Screw</th>
<th>Roller Screw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>&lt;50%</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Load Capacity</td>
<td>Low to Moderate</td>
<td>Moderate to High</td>
<td>High</td>
</tr>
<tr>
<td>Speed</td>
<td>Slow</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Precision</td>
<td>Low</td>
<td>Moderate to High</td>
<td>Moderate to High</td>
</tr>
<tr>
<td>Cost</td>
<td>$</td>
<td>$$</td>
<td>$$$+</td>
</tr>
<tr>
<td>Manufacturing Techniques</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Time to Manufacture</td>
<td>Short</td>
<td>Short</td>
<td>Long</td>
</tr>
<tr>
<td>Audible Noise</td>
<td>Quiet</td>
<td>Noisy</td>
<td>Very noisy</td>
</tr>
<tr>
<td>Back Driving Capacity</td>
<td>Self-locking due to inefficiency</td>
<td>Easily back driven</td>
<td>Easily back driven</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>Low (&lt;60%)</td>
<td>High (100%)</td>
<td>High (100%)</td>
</tr>
<tr>
<td>Life</td>
<td>Low</td>
<td>Moderate to High</td>
<td>High</td>
</tr>
<tr>
<td>Stiffness</td>
<td>Low to Moderate</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Shock Resistance</td>
<td>Moderate to High</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

The table above addresses some of the typical metrics associated with each screw and its relative performance when compared to the other two
Decisions, decisions...

The example below presents an application requiring 1000 lbs force of continuous thrust, over a 10 inch stroke, moving at 12 inches a second, at 100% duty cycle. In this application, the objective is to maximize life out of a particular actuator. Given the high duty cycle of this application, this analysis will focus on ball screw and roller screw options of similar pitches and packaging. The following proposed actuator solutions will be evaluated:

- Parker ETH 80 M10 - 95 mm square frame
- Roller screw competitor ‘A’ -102 mm square frame

Using these two particular actuator series as examples, the load versus life screw technology comparison demonstrates that the ball screw, though slightly smaller in frame, actually has a longer expected life when compared to a similar roller screw actuator. This is largely due to the optimized packaging of the ball screw within the actuator body. The advantage of the ball screw design is even more pronounced when cost is taken into account.

An Engineering Approach

The decision between the two solutions presented is fairly straightforward based upon the above analysis. This can be further quantified through the metrics presented below. It is important to choose the proper technology based on quantifiable metrics rather than product labeling and initial perception.

Step 1 - Identify relevant performance metrics.

Performance metrics are quantifiable outputs that measure the appropriateness of one technology or in this case actuator over another, for an intended application. Metrics which benefit your application such as actuator life, should be maximized. In contrast, metrics which hinder your application, such as cost, should be minimized.

In the application reviewed above three metrics were examined: actuator life, actuator frame size, and cost.

![Load Versus Life](image)

Displayed above is a load-life plot for Parker’s ETH 80 series actuator relative to a competitive rollerscrew actuator.

<table>
<thead>
<tr>
<th>Actuator</th>
<th>Parker ETH 80 (M10 Screw)</th>
<th>Rollerscrew Competitor ‘A’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life at 1000 lbs of Thrust (Millions of Inches of travel)</td>
<td>550</td>
<td>260</td>
</tr>
<tr>
<td>Actuator square frame (mm)</td>
<td>95</td>
<td>102</td>
</tr>
<tr>
<td>Cost ($ USD List)</td>
<td>$3,190.00¹</td>
<td>$5,105.00²</td>
</tr>
</tbody>
</table>

The table above lists the relative performance of two electric cylinders to be evaluated.

¹ List pricing for Parker ETH080M10A1KABFMN0300A
² List pricing for rollerscrew competitor ‘A’ with similar options to the Parker ETH080M10A1KABFMN0300A
Step 2 – Apply the actuator performance equation for each solution.

A relatively simple performance calculation may be used to quantify the relative performance of each actuator solution. Using the form below, characteristics that are ideally maximized, such as actuator life, are input in the numerator, with the maximum across all actuators options input as the denominator. In contrast, characteristics that are ideally minimized, such as cost, are input in the denominator, with the minimum across all actuator solutions input as the numerator.

Step 3 – Score it.

\[
\text{Actuator Performance} = \frac{A \left( \frac{\text{Metric}}{\text{Metric Maximum(Desired)}}_1 \right) *}{B \left( \frac{\text{Metric}}{\text{Metric Maximum (Desired)}}_2 \right) * ...} \]

\[
\frac{C \left( \frac{\text{Metric Minimum(Undesired)}}{\text{Metric}}_1 \right) *}{D \left( \frac{\text{Metric Minimum (Undesired)}}{\text{Metric}}_2 \right) * ...}
\]

This calculation takes into account each critical aspect of actuator performance and quantifies it. Weights can be applied to each of the metrics by assigning the coefficients A, B, C, and D a relative value. Using this equation with no weights the best solution should yield the score closest to 1.

also be used to weight one metric higher than another. Given this model, the higher the performance score, the more ideal the actuator. Using this example, as well as the metrics of life, frame width, and cost with even weight results in the following calculations:

\[
\text{ETH Performance} = \frac{550 \text{ Million Inches}}{550 \text{ Million Inches}_{\text{Life}}} * \frac{3.74 \text{ Inches}}{3.74 \text{ Inches}_{\text{Frame Width}}} * \frac{$3,190.00}{$3,190.00}_{\text{Cost}} = 1.0
\]

\[
\text{Roller screw competitor 'A' Performance} = \frac{260 \text{ Million Inches}}{550 \text{ Million Inches}_{\text{Life}}} * \frac{3.74 \text{ Inches}}{4.00 \text{ Inches}_{\text{Frame Width}}} * \frac{$3,190.00}{$5,105.00}_{\text{Cost}} = 0.276
\]

Though on paper these electric cylinders might seem to have similar performance, once their relative performance is weighed using the actuator performance calculator proposed, the collective differences become quite evident.
Other Considerations

Aside from performance and cost, it is also important to consider how easy it is to source a given technology. Ball and lead screws are manufactured by numerous suppliers worldwide. In contrast, there are very few manufacturers of roller screws. When designing a motion application in a global market, the availability of a given technology may be a deciding factor. With few manufactures in limited locations there is the possibility that design issues may be presented in the event that manufacturer ever leaves the screw making industry.

Closing Thoughts

In closing, there is not a ‘one size fits all’ technology for every application. In reality, the selection depends entirely upon the application and what is most important to you. Deciding between all the different options available can be daunting to a designer, but approaching the application systematically by applying an actuator performance calculation as outlined in this paper will aid in the decision making process.

About the Author:

Travis Schneider, is a product manager for Parker’s automation group focussing on precision linear mechanics. Travis has an extensive background in motion and control and has worked hand-in-hand with many designers implementing electromechanical systems. Travis received his B.S. in Mechanical Engineering from the Milwaukee School of Engineering.