

NOISE AND VIBRATION IN LEADSCREW-DRIVEN MOTION DESIGNS AND HOW TO AVOID THEM

Leadscrews — especially those with high-accuracy threads — can be a low-vibration alternative to other linear-motion options. That's in part because of the consistent contact between their load-bearing mating subcomponents.

This smooth operation of leadscrews is indispensable to an array of applications. In some medical devices, machine axes run by leadscrews are almost silent to nearby patients and medical personnel — increasing the comfort of diagnostic and treatment settings. In printing and scanning machines, leadscrews minimize vibration to allow devices to output product with greater consistency.

LEADSCREW NUTS TO REDUCE OR ELIMINATE SIGNIFICANT VIBRATION

Leadscrews are quieter than ballscrews, especially when compared to ballscrews with recirculating-ball nuts (and their deflector impacts and clattering of balls entering and exiting loaded zones). In these rotary-to-linear devices, even microscopic variations on the ballscrew shaft greatly amplify sound emitted.



But just as the friction of a violin bow across its strings induces vibration and sound, so too can friction between a leadscrew shaft and nut. Sliding contact in leadscrews means friction values affect overall efficiency, output torque, wear, and dynamic stability ... and can induce vibrations that deteriorate system performance.

A leadscrew's nut-to-shaft coefficient of friction is velocity-dependent. It (along with system damping and stiffness) partially defines leadscrew system dynamics.

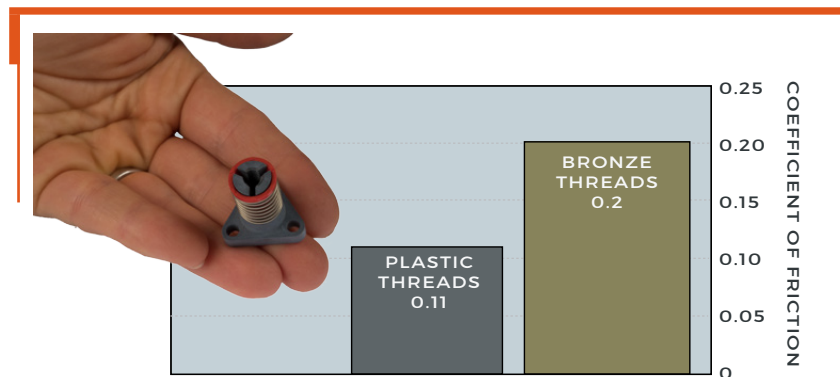
Consider how friction-induced vibration is a common phenomenon in leadscrews using typical metallic nuts of brass or bronze. Here, alternatives are precision leadscrew nuts made of engineered self-lubricating plastics and other polymers, including base materials of acetal, nylon, PPS, and PEEK, with optional fiber reinforcement including carbon, aramid, and glass.

These nuts achieve especially quiet operation, better overall performance, and can be tailored to the specific application need. Their low-friction sliding helps keep noise to a minimum. For example, engineered polyacetal nuts can keep the nut-screw friction coefficient to less than 0.10 for exceptionally quiet operation — and eliminate the need for lubrication.

Additionally, when addressing noise and vibration it important to understand the variation between dynamic (or sliding) friction and static (or break away) friction. As the delta between dynamic and static coefficient of friction increases, so does the risk of slip-stick-induced vibration and noise. When possible it's best to select material combinations that have similar static and dynamic coefficients of friction to minimize this risk.

ZBX Series anti-backlash leadscrew nuts and shafts deliver precise positional accuracy but are cost effective. Standard ZBX leadscrew assemblies include a 303-stainless steel screw and radially preloaded polyacetal nut that's self-lubricating. The transfer of loads ensures torque consistency; the nut's inherent damping help it excel in vertical applications needing vibration control.

THERMOPLASTIC LEADSCREW NUTS REDUCE FRICTION



Many leadscrew nuts are made of bearing-grade bronze because the material readily accepts internal-thread machining ... But there's compromise on both lubricity and physical stability. In contrast, leadscrew nuts made of lubricated thermoplastic material last longer and exhibit less friction.

LEADSCREW NUT COMPENSATION MECHANISMS

STANDARD BACKLASH COMPENSATION: A SPRING BRIDGES SPLIT NUTS.

OTHER BACKLASH COMPENSATION: STIFF LINK BRIDGES SPLIT NUTS.

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THE DRAWBACK IS A NEED FOR LINK REPLACEMENT.

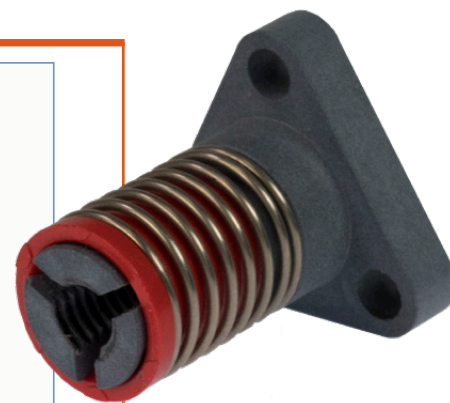
AUTOMATIC COMPENSATION: SELF-ADJUSTING LINK EXPANDS NUT.

Often backlash compensation takes the form of nut halves biased with a spring. This imparts directional stiffness towards the loading of the nut half (against the screw thread flank) but not away from that thread. So the nut axial stiffness depends on the spring-applied preload. That in turn means preload must meet or exceed the maximum axial load the axis carries ... which unfortunately increases drag torque and wear. Higher loads at the screw-to-nut interface also necessitate more torque input to drive the leadscrew.

In contrast, leadscrew nuts with a stiff but expanding spacer between the nut halves avoid excessive preload by continually elongating as the nut threads wear. Such nuts carry axial loads bidirectionally with no backlash.

- The nut spacer is threaded at one end and has a complementary nut torsionally biased to advance when the nut assembly expands.
- Once expanded, the spacer relies on fine helix threads to prevent backdriving under axial load.

Preload is independent of external loads, so is of a magnitude that's sufficient to turn the spacer nut on the spacer rod (and no more). Axial stiffness is a result of the compliance of the nut and spacer materials, and not the rate of the spring. This makes for a self-compensating unit to correct for wear with axial stiffness but minimal frictional drag.



E25542-12-900 Haydon Kerk
can-stack linear actuator

Another way in which nuts minimize vibration is to keep lost motion at bay.

Recall that degradation of mechanical leadscrew designs usually manifests as gradual wear. Anti-backlash nuts can automatically compensate for this issue. Such nuts ensure zero-backlash operation with very light preloading. That in turn leads back to the topic of quiet operation, as noise from leadscrew axes (as with any other mechanical design) generally increases with loose connections.

Differences between anti-backlash nut designs impact their ability to reduce noise and vibration. Consider one example of a leadscrew incorporating an anti-backlash nut — the ZBA Series from Haydon Kerk of AMETEK Advanced Motion Solutions (AMS). ZBA-Series leadscrew assemblies rely

on the compression of an O-ring in a collar to apply radial pressure to the nut. Just as other standard Haydon Kerk anti-backlash leadscrew nuts (such as NTB and WDG Series offerings, for example) these provide wear and backlash compensation.

In general, anti-backlash nut technology that removes radial clearance (such as the ZBA) has favorable noise and vibration damping characteristics over anti-backlash nut technology that removes axial clearances. This makes them particularly well suited for applications that require smooth motion — as in scanning, printing, and plotting, for example.

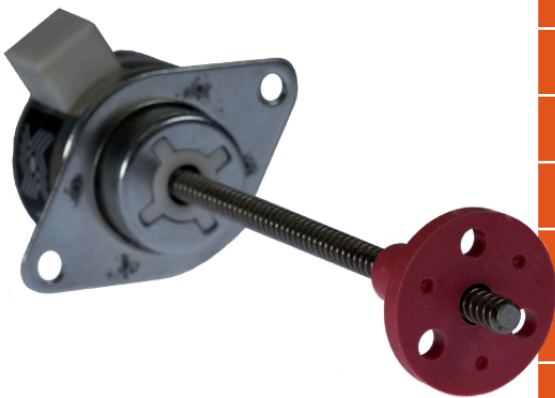
Even more common are Haydon Kerk ZBX Series leadscrews. These linear devices are widely used in an array of industries for their wear compensation.

In fact, the ZBA and ZBX both close inward (radially) on the thread root to limit lost motion (and vibration) between the nut and screw. However, ZBX leadscrew assemblies use the expansion of an axial spring to force the collar up a ramp to close internal fingers inward. That means ZBX leadscrews ultimately have longer life and more wear compensation than ZBA leadscrews.

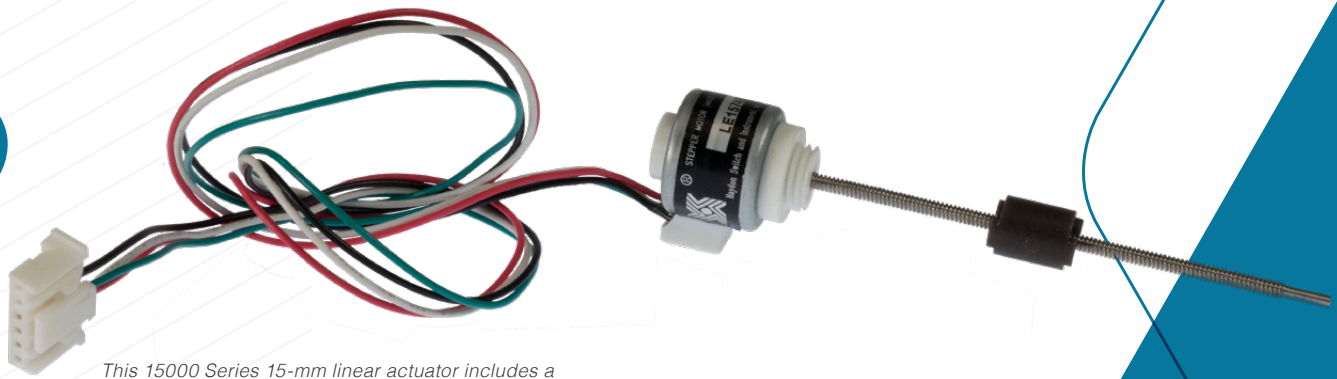


ZBA Series anti-backlash nuts and leadscrew assemblies ensure positional accuracy and consistent motion for an array of plotting, printing, and scanning machines. Manual adjustment of drag torque allows for matching of application or customer specifications. ZBA Series nuts also excel at damping vibration.

Standard variations on these Haydon Kerk leadscrew nuts abound and are often modifiable to meet specific application requirements. Custom Haydon Kerk leadscrew options are also possible where application parameters and volumes justify them. Sometimes on advanced



Leadscrew nut parameter	ZBX	ZBA
Vibration damping (horizontal)	★★★★	★★★★
Vibration damping (vertical)	★★★★	★★★★
Smoothness of operation (printing, scanning)	★★★	★★★★
Backlash/wear compensation capability	★★★	★
Ease of user-adjustable drag torque and backlash	Not applicable	★★★★
Stiffness (less axial bidirectional compliance)	★★★	★★★



This 15000 Series 15-mm linear actuator includes a self-lubricating ZBM nut. The nuts come in acetyl and kerkite performance composite polymers.

applications, engineers will even use numerical simulation and prototyping to predict regions of dynamic stability for ranges of axis speeds and loads — and then adjust leadscrew damping and stiffness to boost performance.

Note that for particularly small machine designs, there are micro-series leadscrews and mating anti-backlash nuts to prevent vibration. ZBM Series leadscrew nuts and assemblies from Haydon Kerk of AMETEK AMS are leading solutions. As with other Z-name Haydon

Kerk leadscrew nuts, these ZBM Series offerings include a mechanism that radially closes in on the nut to eliminate radial clearance and avoid noise.

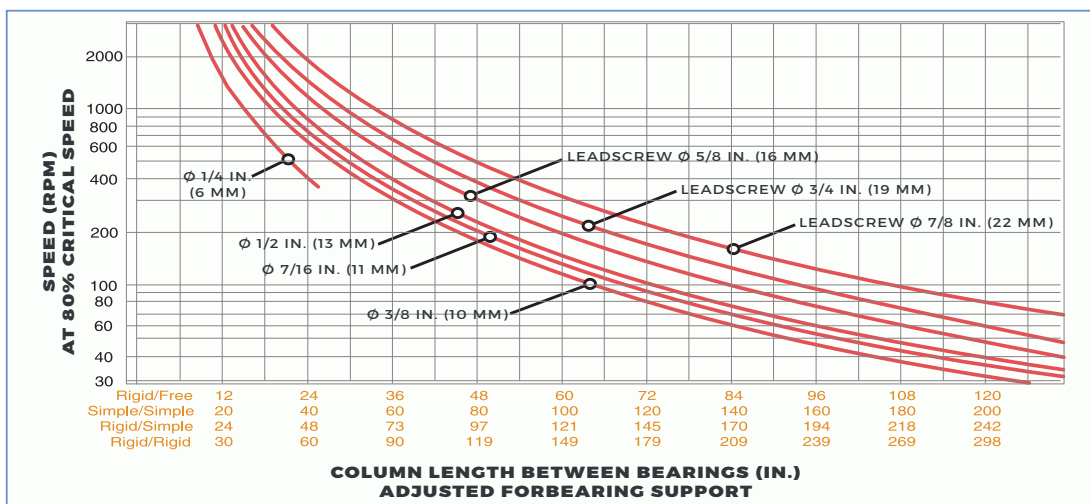
LEADSCREW SHAFT DESIGN FOR VIBRATION AND NOISE MINIMIZATION

Leadscrew shaft designs also affect how a linear axis will exhibit vibration. All leadscrews (and ballscrews) have a value called critical speed — a quantification of axis natural frequencies that (if the application exceeds or excites) can cause severe vibration and noise.

More specifically, critical speed is defined by end fixity and leadscrew-shaft length and diameter:

$$\text{Critical speed } S \text{ (rpm)} = MF \times 4.7 \times 10^6 \times RD/L^2$$

LEADSCREW CRITICAL SPEED



Critical speed is the rotational speed at which a leadscrew exhibits dynamic issues such as vibration. Shown here is a plot to help design engineers determine if application parameters will approach a leadscrew's critical speed. Design engineers can avoid noise and vibration issues by increasing critical speed with a longer lead, larger shaft diameter, or more bearing supports.

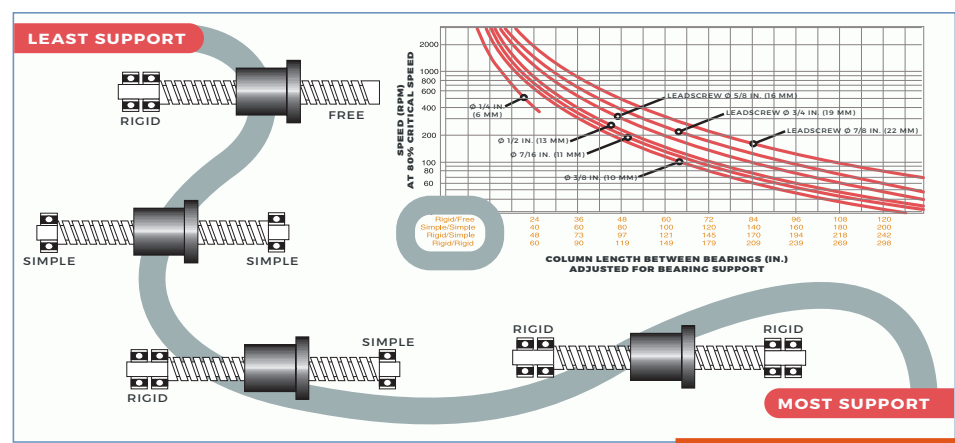
LEADSCREW END SUPPORTS AFFECT CRITICAL SPEED

Where MF = Factor to account for the effect of mounting supports; RD = Leadscrew root diameter (in.); and L = Length between supports in inches.

One rule of thumb is that application speed should be no more than 85% of the leadscrew's first-order critical speed. Long axes necessitating long strokes tend to increase the likelihood of leadscrew vibration and noise. That's because the operating ranges of longer leadscrews are more likely to excite natural frequencies. But leadscrew length usually depends on the application requirements, so usually diameter and end bearings are changed if critical speed threatens to be an issue.

Beyond critical speed, other leadscrew-shaft features affect vibration and noise generation. Today's leadscrew shafts are specifically designed for rotary-to-linear motion, so include trapezoidal, buttress, or rounded (knuckle) threads. Rounded teeth in particular can reduce nut-to-shaft surface contact even while maintaining thrust capacity. This in turn minimizes the generation and transmission of vibration.

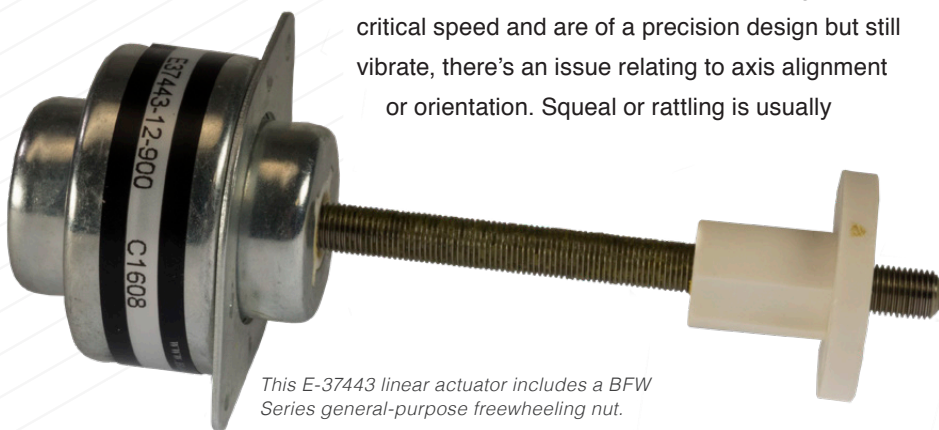
Sometimes when leadscrews are operating below critical speed and are of a precision design but still vibrate, there's an issue relating to axis alignment or orientation. Squeal or rattling is usually



Leadscrew length is usually set by application requirements. So where critical speed maybe an issue, engineers will often upgrade end supports.

the first sign of these problems. Often the underlying source of misalignment is wobble or runout at the leadscrew-to-motor connection — especially in cases where the OEM or end user assumes the task of coupling these two components. Solutions include improvements to mounting or actuator alignment, a lowering of axis speed, or integration of subcomponents for vibration mitigation.

One final note: Vibration and noise are system considerations, so preventing these issues at the leadscrew is only one step of many for full assembly specification.



This E-37443 linear actuator includes a BFW Series general-purpose freewheeling nut.

For more information, visit
[HAYDONKERKPITTMAN.COM/
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