

Introduction to Lead Screw Selection

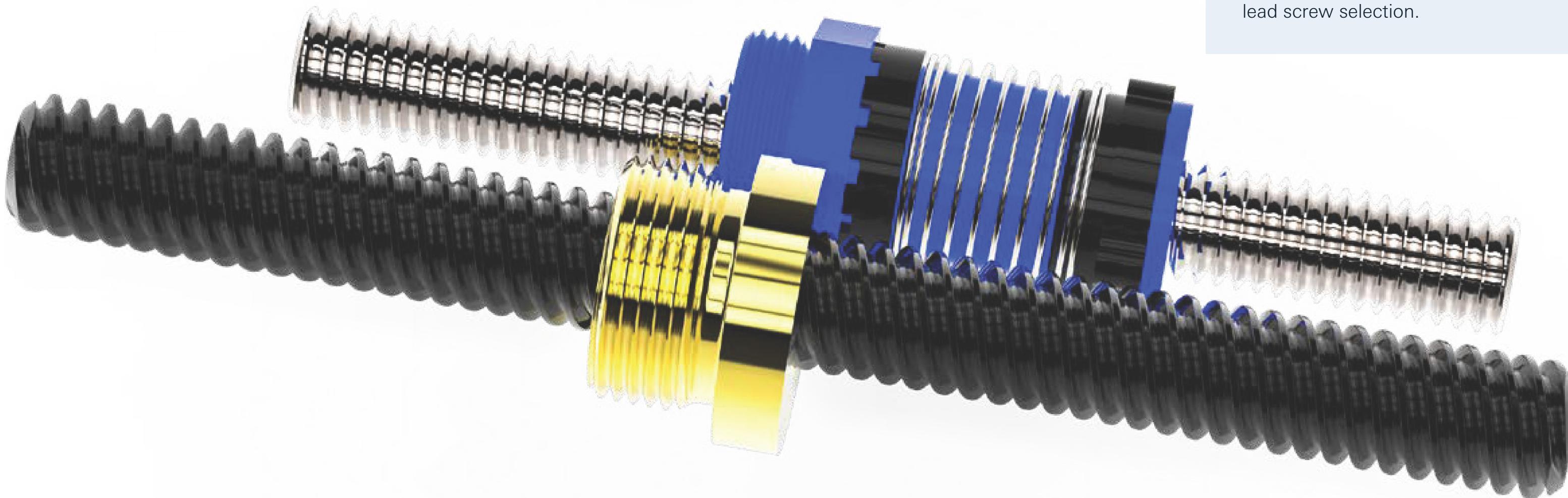
HELIXTM
LINEAR TECHNOLOGIES

Selecting a Lead Screw

Introduction

This step-by-step guide for selecting a lead screw will address the critical attributes in establishing the best lead screw, nut type and material for your application. Following these steps will help achieve optimal performance, accuracy and service life.

Lead screws play a vital role in mechanical systems, converting rotary motion into linear motion. They are commonly used in various applications, including industrial machinery, automation systems, and 3D printers to name just a few.



What is a Lead Screw?

Before we delve into the details, let's briefly understand the fundamentals. A lead screw assembly consists of a screw and a nut with helical grooves running along their surfaces. As the screw rotates, the nut moves along the axis of the screw. The distance the nut advances in one revolution is known as the lead, the key parameter in lead screw selection.

Selecting a Lead Screw

Your system's needs



There are as many different screws as there are applications that employ them. Choosing the right one for your project can help you achieve more than you ever thought possible. Before designing your next solution, remember to look at each of the following aspects of your application before choosing the right screw for your linear motion needs.

Thrust

Thrust is the amount of push that must be given to the screw to move it and its load. There are two types of thrust—peak and continuous. Peak thrust is a short burst during acceleration while continuous thrust occurs during the full linear motion application. The greater the thrust requirements are for a given application, the larger the diameter of the screw must be to meet those requirements.

Speed

How fast will the linear motion occur in your application? All lead screws have a critical velocity. This is a speed at which they will no longer perform at their best due to vibrations within the motion. There is a ratio that directly shows the velocity of the screw based on input RPM (rotations per minute.) A larger screw reduces the RPM in high-speed applications, so the more significant the screw you use, the lower the potential RPM.

Accuracy

Accuracy measures moving the load to the location while retaining a tolerance level. If you must maintain high accuracy, a highly accurate lead screw is essential. Screws with a higher accuracy level are generally more expensive, but accuracy is critical for specific applications' success.

Repeatability

While many confuse repeatability with accuracy, these are different considerations. Repeatability measures how well the screw moves the load to the same position -time after time. This is more important than accuracy in many applications, and some of our Helix lead screw assemblies are better suited to meet this need than others.



Selecting a Lead Screw (cont'd)

Your system's needs

Backlash

The amount of linear movement put in place between the screw and the nut without actually turning either is referred to as backlash. In specific applications, too much backlash can lead to problems. Axial Anti-Backlash screw assemblies are highly effective at reducing the amount of backlash within the system. Reducing backlash lowers the wear on all pieces and can improve the overall accuracy as well.

Resolution

The resolution of a linear actuator is the distance traveled at the smallest rotational move possible. Resolution is typically thought of as something controlled by the motor and controller of the linear tool. However, choosing the correct lead screw can also affect this to a small degree. A smaller diameter screw may require a less-powerful motor to achieve the exact resolution as a larger diameter screw.



Application Requirements

Load, Movement, Environment

The next step in selecting a lead screw is to clearly define the requirements of your specific application. This includes understanding the load characteristics, movement requirements, and environmental conditions.

Load capacity requirements are the first consideration when an application incorporates a lead screw. For the strongest assembly, the lead screw nut should pull the load in tension rather than compression to avoid buckling. However, if they must be in compression, determine the nuts' maximum dynamic load values. Determine the weight of the object being moved or lifted and any additional forces that will act on it during operation. Identify the direction and magnitude of these forces, as they will impact the torque and load capacity of the lead screw.)

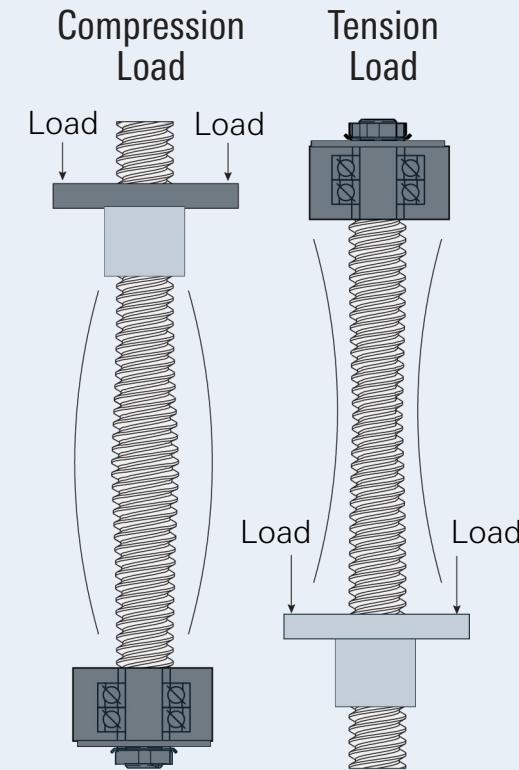
Speed is the rotational speed in RPM which is equal to the linear speed in inches per minute divided by the inches per revolution of the lead of the screw. If necessary, increase the screw diameter when the required RPM is greater than a safe speed for the application. When increasing the screw lead decrease the RPM or increase end strength to provide more rigidity. Determine the desired speed at which the load needs to be moved. This will influence the selection of the lead screw pitch and the number of revolutions required to achieve the desired linear motion.

Environmental Conditions: Evaluate the environmental factors that could affect the lead screw's performance. Consider temperature variations, humidity levels, the presence of dust or debris, and the possibility of exposure to corrosive or abrasive materials. Does your system require a clean room? Do you require food grade materials?



Types of Load

Tension Load: A load that tends to "stretch" the screw.

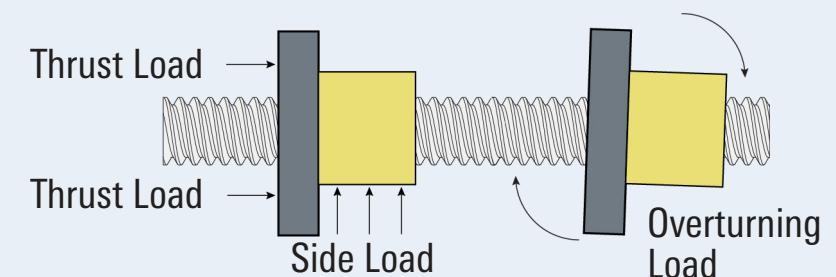


Compression Load: A load that tends to "squeeze" the screw.

Thrust Load: A load parallel to and concentric with the axis of the screw.

Overturning Load: A load that tends to rotate the nut radially around the longitudinal axis of the screw.

Side Load: A load that is applied radially to the nut.



Calculate the Required Torque

What are your power capabilities?

Once the load requirements are defined, the next step is to calculate the torque required to move the load.

Torque is the rotational force needed to generate linear motion in the lead screw.

Consider the following factors:

Major Diameter: The outside diameter of the screw. Sometimes called Land Diameter.

Minor Diameter: The diameter of the screw measured at the bottom of the thread.

Sometimes called Root Diameter.

Pitch Diameter: The diameter at which the thread thickness is equal to the space between threads.

On a lead screw, this diameter is approximately halfway between the land diameter and the root diameter.

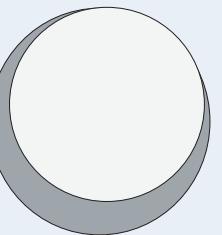
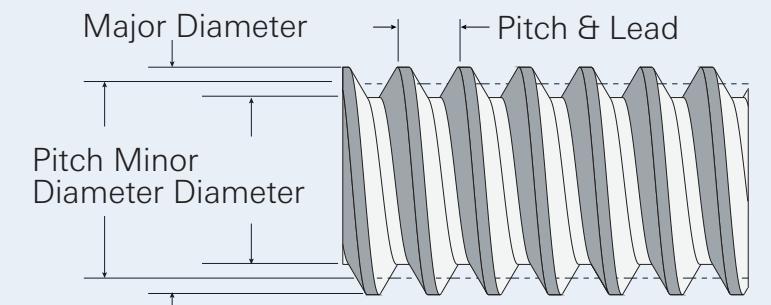
Pitch: The pitch is the distance traveled axially with each complete revolution of the lead screw. It determines the linear motion achieved per revolution and influences the torque requirements. Higher pitch leads to greater linear displacement per revolution but may require higher torque. Pitch is equal to the lead in a single start screw.

Lead: The axial distance the nut advances in one evolution of the screw. The lead is equal to the pitch times the number of starts. $\text{Lead} = \text{Pitch} \times \text{Starts}$

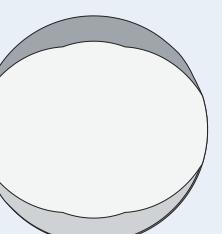
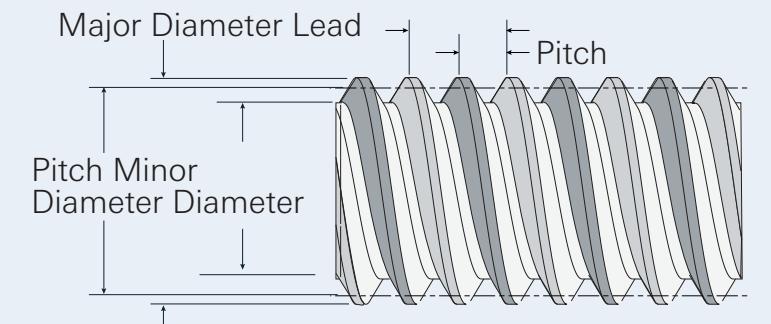
Screw Starts: The number of independent threads on the screw shaft; example one, two or four.

Screw Starts

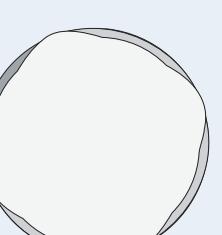
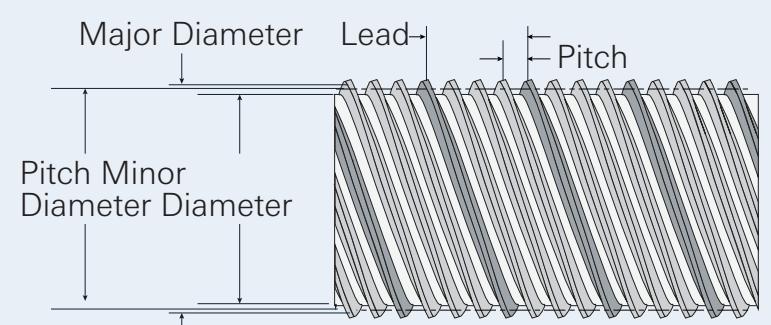
Single Start



Double Start



Four Start



Calculate the Required Torque

Accuracy, friction, and efficiency

Lead Accuracy: Lead accuracy is the difference between the actual distance traveled versus the theoretical distance traveled based on lead. For example: a screw with a .500 inch lead and .0003 in/in lead accuracy rotated 24 times, theoretically moves the nut 12 inches ($24 \text{ revolutions} \times .500 \text{ inches per revolution} = 12.000 \text{ inches of travel}$). With a lead accuracy of .0003 in/in, actual travel could be from 11.996 to 12.004 inches.

Coefficient of Friction: Determine the coefficient of friction between the lead screw and the nut or any other moving components. It is essential to account for this frictional force while calculating the required torque.

Efficiency: Consider the efficiency of the lead screw system. Efficiency is the ratio of output power to input power and takes into account losses due to friction and other factors. Higher efficiency reduces the required torque.



Acme Screws & Threads

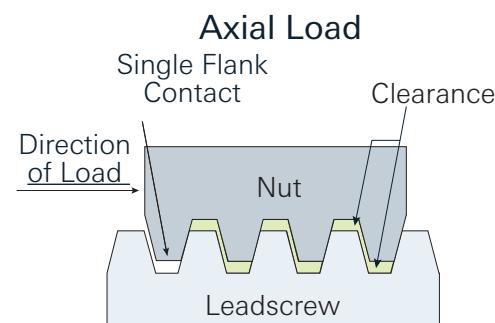
Acme screws are a type of lead screw and are more economical than other options such as ball screws. The acme thread is easier to machine and has very favorable properties for power transmission. There are three main classes of acme thread forms:

- General Purpose (G)
- Centralizing (C)
- Stub Acme

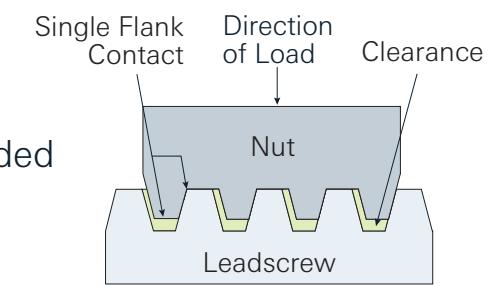
General purpose and centralizing threads incorporate a nominal depth of thread of $0.50 \times \text{pitch}$ with a 29° included thread angle, an angle that is formed by two sides of a polygon and share a common vertex.

When compared to general-purpose thread forms, centralizing threads are manufactured with tighter tolerances and reduced clearance on the major diameter.

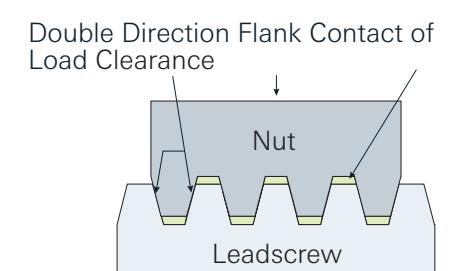
Stub acme has a thread depth of less than one half the pitch but follows the same basic design as general purpose and centralizing threads. Used typically in small spaces, a shortened, truncated, or "Stubbed" thread is utilized where applications necessitate a shallow depth, coarse pitch thread.



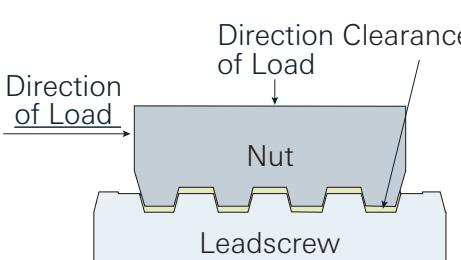
Radial Load on a General Purpose Nut



Radial Load on a Centralizing Nut



Stub Thread



Determine the Lead Screw Material

The core strength of your application

The material selection for the lead screw is influenced by various factors, including load requirements, environmental conditions, and budget considerations.

Common materials used for lead screws include:

Alloy Steel: Alloy 4140 steel has good fatigue strength, as well as a high tensile strength and high torsional strength. This is the most commonly used material in leadscrew applications.

Stainless Steel: Stainless steel is known for its excellent corrosion resistance, making it suitable for applications exposed to moisture or corrosive environments.

Carbon Steel: Carbon steel offers good strength and wear resistance at a lower cost compared to stainless steel. It is commonly used for moderate load applications.

Bronze: Bronze is often chosen for its self-lubricating properties, which reduce friction and wear between the screw and nut. It is suitable for applications where lubrication may be limited or difficult.

Plastic: Certain plastic materials, such as Delrin (polyoxymethylene) or nylon, can be used for low-load or low-speed applications. They offer low friction, self-lubricating properties, and resistance to chemicals.

The material selection should align with the load requirements, environmental conditions, and the desired performance characteristics of the lead screw.

Lead Screw Grease

Lead screw grease is a type of lubricant used to reduce friction and wear between the rotating lead screw and its mating nut, thus improving the performance and lifespan of the lead screw assembly. There are several types of lead screw grease designed to meet specific requirements and operating conditions.

Lithium Soap-Based Grease

One of the most commonly used types of lead screw grease, lithium soap-based grease is an excellent general-purpose grease that provides good lubrication and protects against corrosion.

Synthetic Grease

Made from synthetic oil, this grease is engineered to provide enhanced performance and protection in high-temperature, high-speed, and high-load applications.

High-Temperature Grease

This grease is formulated to maintain consistency and lubrication at high

temperatures. Made from synthetic oil with high-temperature stabilizing additives, it provides excellent resistance to oxidation and thermal degradation.

Water-Resistant Grease

Water-resistant grease is formulated to resist the effects of water, preventing the grease from washing away and leaving the lead screw assembly unprotected. Water-resistant grease provides excellent protection against corrosion.

Heavy-Duty Grease

Heavy-duty grease is designed for high-load, high-stress applications. It is formulated for enhanced wear protection, reducing friction between the lead screw and nut.

Food-Grade Grease

Designed for use in food processing and packaging applications, this grease is made with food-safe ingredients and meets strict food safety regulations.

Determining Nut Type and Material

How much, how fast, and with what precision?



The choice of lead screw material could be irrelevant without the proper selection of the nut material. The compatibility of lead screw and nut materials for the particular application is critical for smooth and reliable operation of the lead screw.

Nut materials are typically bronze, acetal, or other high-performance polymers. Each provides variable amounts of:

- Wear
- Thread protection
- Load
- Lubrication
- Temperature

System performance depends heavily on the selection of nut types. The benefits of anti-backlash or preloaded nuts can play an important role in achieving desired performance characteristics; however, they must be thoroughly evaluated to ensure compatibility with system requirements.

First establish the required load capacity. Bronze is especially well-suited for applications with extremely heavy loads or exceptionally high (or low) temperatures. On the other hand, plastic nuts are typically used for light loads, however depending on the thread diameter and lead size, plastic nut designs can handle very heavy loads.

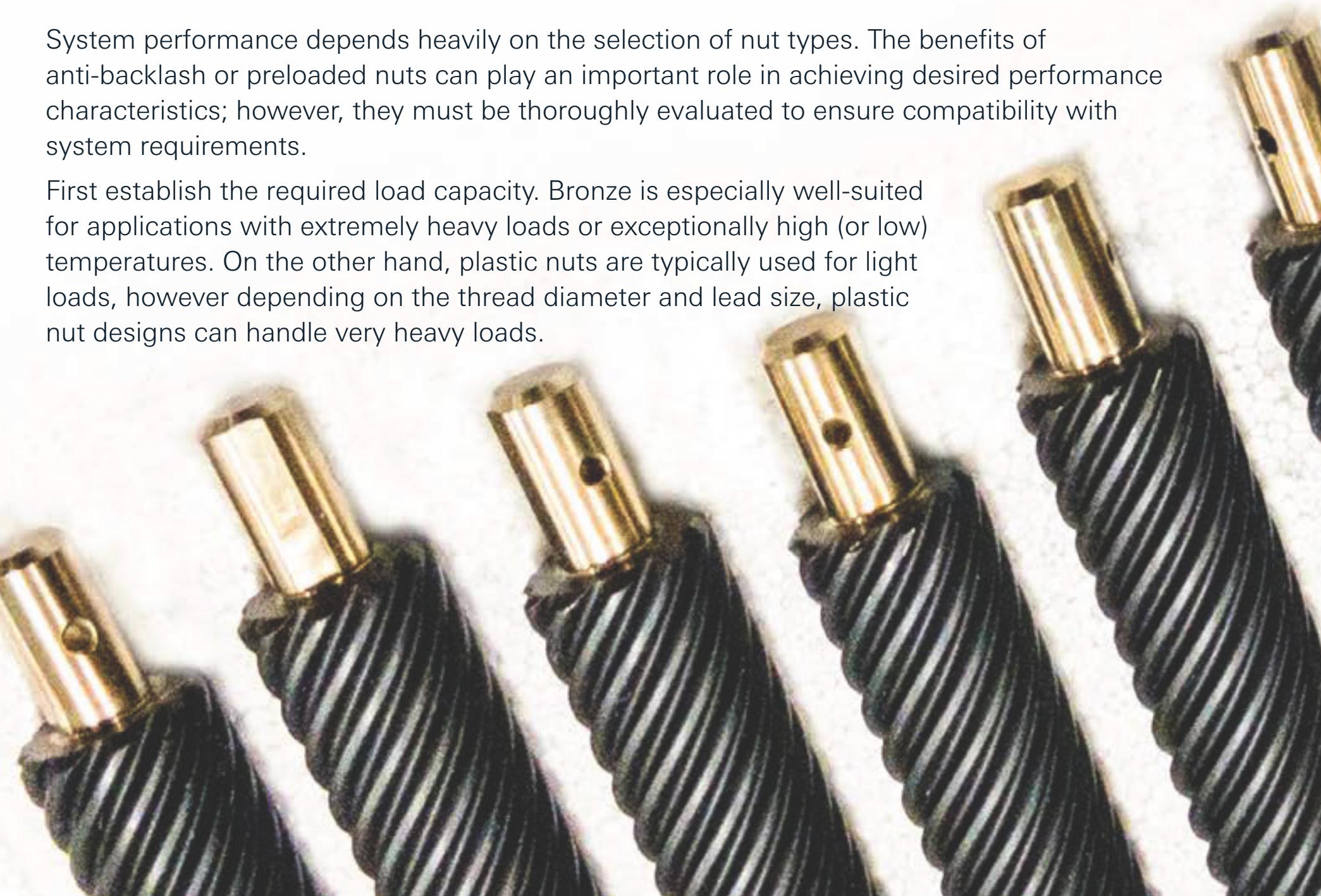
Consider the Required Accuracy

The required accuracy of the lead screw system depends on the specific application. Some applications, such as industrial automation or CNC machines, require high precision and repeatability. Other applications may have more relaxed accuracy requirements.

Thread Accuracy: The lead screw's manufacturing tolerance and precision affect its accuracy. Threads with higher accuracy result in smoother and more precise motion.

Backlash: As discussed previously, backlash can have a profound affect on the accuracy of your linear motion application.

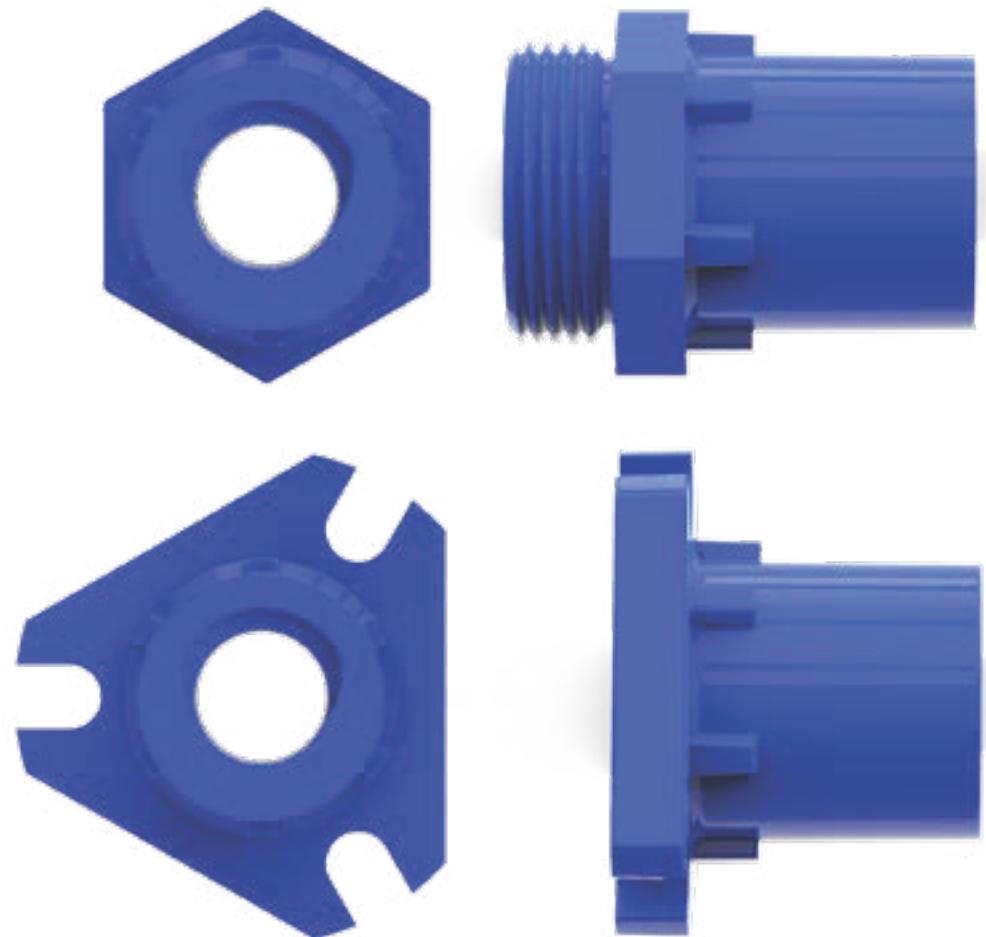
Nut Type: Different types of nuts, such as standard nuts, anti-backlash nuts, or preloaded nuts, can be chosen to improve accuracy and reduce backlash.



Determining Nut Type & Material

Freewheeling Nuts

Freewheeling nuts are beneficial in motion control applications where the highest precision is not necessary. They have low drag torque because they are designed with clearance between the nut and screw thread, which results in a small amount of lost motion. They therefore may not provide the same level of precision and accuracy as anti-backlash nuts.

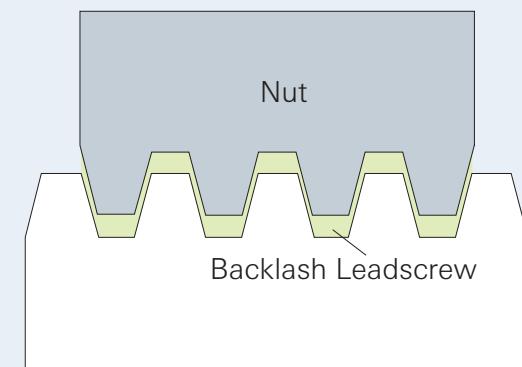


Freewheeling nuts are less expensive than anti-backlash nuts and have a higher dynamic load rating. However, they are subject to intrinsic backlash, which can lead to inaccurate positioning.



Backlash

Backlash in a lead screw application refers to the play or clearance between the threads of the screw and the corresponding threads in the nut. It's like a little bit of free movement before the nut engages or disengages with the threads of the screw.



Imagine tightening a screw: you turn it a bit before you feel resistance, right? That initial turn where nothing happens is the backlash. In lead screw applications, backlash can be a concern because it can result in imprecise movements and reduced accuracy.

Especially in applications where precision is crucial, such as CNC machines or 3D printers.

Backlash is very likely to intensify with wear and be extremely detrimental to the application.

However, anti-backlash nuts minimize or eliminate backlash, which improves system precision and accuracy, especially over time.

Determining Nut Type & Material

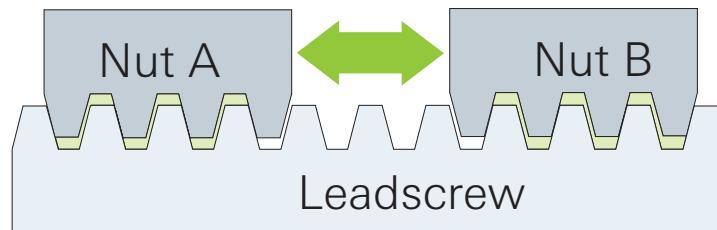
Anti-Backlash Nuts



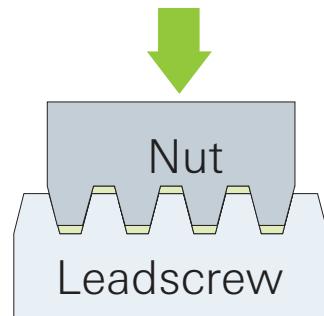
Anti-backlash nuts are ideal for applications that require high precision and accuracy in linear motion. They incorporate a spring-loaded mechanism that minimizes or eliminates backlash, resulting in more accurate and repeatable linear motion. Their design compensates for wear over time.



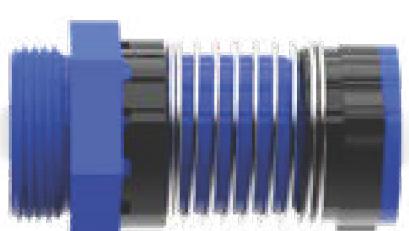
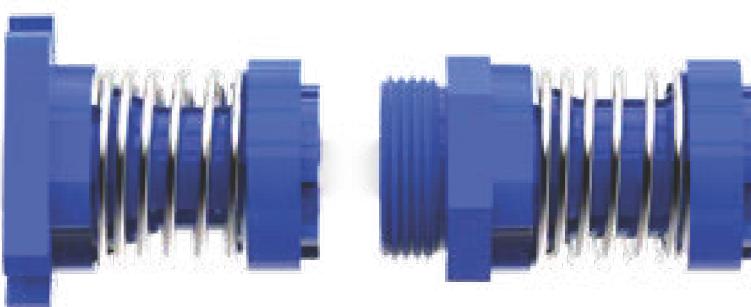
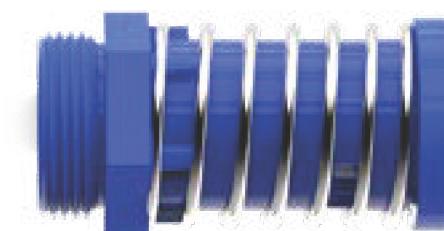
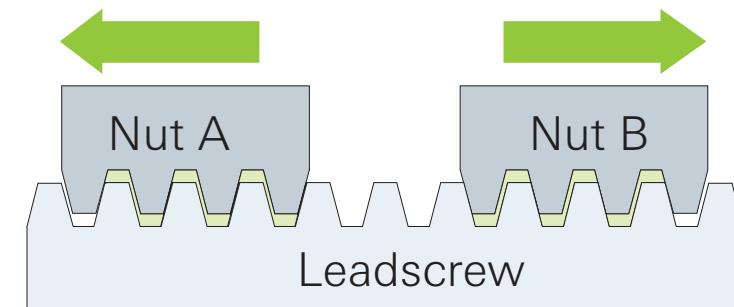
Axial Anti-Backlash nuts have different spring options: high force, normal, and micro force. They are easy to manufacture and customize, and are work well with light loads.



Radial Anti-Backlash nuts work well in vertical and vibration-prone applications. They have lower drag torque than axial anti-backlash nuts.



Torsional Anti-Backlash Nuts are perfect for use in high load, high speed, and/or low torque applications. They are stiff in compression and are the lowest drag torque option available.



Choose End Fixity Options

An essential component that plays a critical role in the working of a lead screw assembly and determines its stability and critical speed is the end fixity.

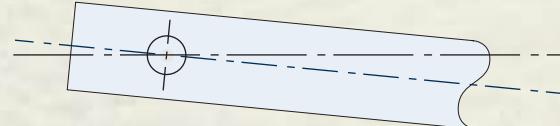
End fixity, also known as the support method, refers to the way the lead screw ends are supported. It directly impacts the critical speed – the speed at which a lead screw will begin to resonate or wobble – the column strength, buckling load, and hence, the overall performance of the lead screw assembly.

Three basic types of end fixity

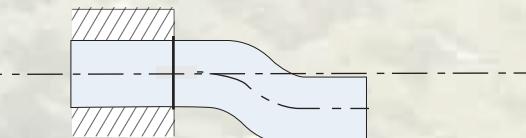
Free No support



Simple Restrained against radial and/or axial loads



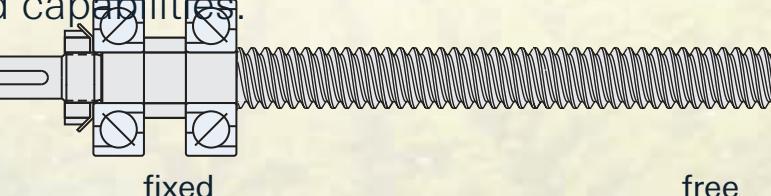
Fixed Shaft rigidly restrained against radial, axial and moment loads



These can be configured in four different ways:

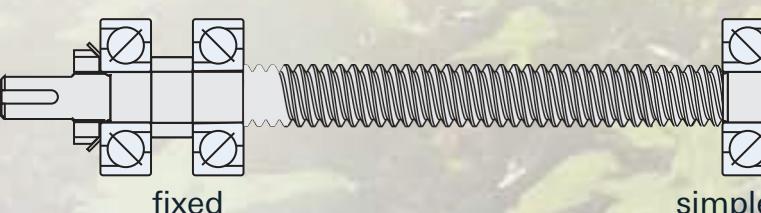
Fixed/Free

This configuration involves fixing one end of a lead screw, leaving the other end free and unsupported. This configuration is often employed in applications that need high speeds but lower load capabilities.



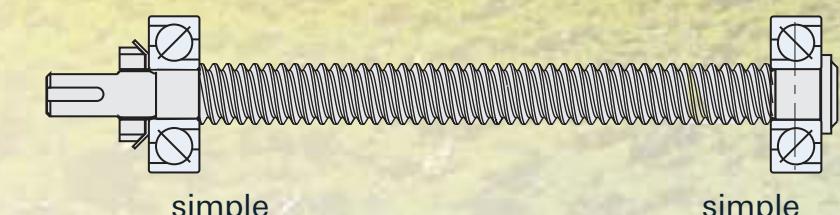
Fixed/Simple

This configuration provides support both axially and radially, which allows for higher critical speeds as well as buckling loads. It also allows for thermal expansion.



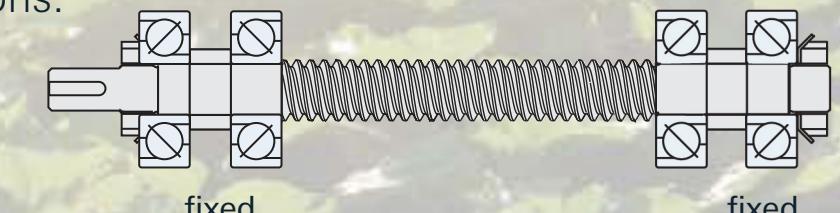
Simple/Simple

This method supports both ends of the lead screw. Such support offers balance in load-bearing and speed capabilities. It is most suitable for applications that need medium to high-speeds.



Fixed/Fixed

In this configuration, both ends of the lead screw are tightly held or fixed. This method drastically increases the critical speed and load-bearing capability of the lead screw assembly, making it most suited for high-performance applications.



Final Considerations

Ensuring you have the optimal linear motion solution



Evaluate Cost and Lead Time

Consider the cost and lead time associated with the selected lead screw. If cost and lead time are the main drivers for your project, review your selected options to better understand the actual cost drivers once you have received a quotation. Additionally, consider lead times to ensure that the required lead screw assembly can be delivered within the desired timeframe.

Seek Expert Advice and Supplier Support

Selecting the right lead screw can be a complex process. It is recommended to consult with experienced manufacturers or suppliers who can provide expertise and guidance. They can assist in evaluating the application requirements, offer suitable options, and help address any specific challenges or constraints.

Validate the Selection

Before finalizing the lead screw selection, it is advisable to validate the choice through prototype testing or simulations. This step ensures that the lead screw meets the expected performance criteria and satisfies the application requirements.

In summary, selecting the correct lead screw involves defining the application requirements, calculating the required torque, selecting the appropriate lead screw type and material, considering the required accuracy, evaluating cost and lead time, and seeking expert advice. By following this systematic approach, engineers can confidently choose the optimal lead screw that will deliver reliable and efficient performance for their specific application.



Conclusion

Proper selection, material and lubrication considerations for lead screws are essential to system performance and service life. And not to just the lead screw assembly itself, but also for operation in the specific applications. Lead screws can be exposed to harsh environments or **very** clean conditions. From CNC machines to 3D printers, robotic systems to linear actuators and even lead screw driven mini actuators for printed circuit board assembly, lead screws play an important role in a wide variety of manufacturing applications.

By following the steps outlined here, engineers and equipment operators can make knowledgeable assessments in the appropriate selection of lead screws, nut types, and lubrication for their specific applications. Understanding and applying these steps to lead screw assembly and nut selection will assist in achieving the expected accuracy, required performance characteristics and system service life.



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