The Engineer’s Guide to Selecting a Lead Screw

The most important factors to consider when selecting a lead screw for an application.

HELIX™
LINEAR TECHNOLOGIES

Lead Screw Selection

Lead screws use the ***helix*** angle of the thread to convert rotary motion into ***linear motion***. To determine the lead screw and nut combination for your application, the following interrelated factors must be identified and considered:

1. Axial Load
2. Speed
3. Screw Inertia
4. Torque
5. Inertial Torque
6. Drag Torque
7. Torque-to-Move
8. Back Driving
9. Length
10. End Fixity

1. Load

Measured in pounds or newtons; the loads that need to be considered are the **static loads**, **dynamic loads**, **reaction forces** and any **external forces** affecting the screw.

- **Static Load –** The maximum thrust load – including stock – that should be applied to a non-moving acme nut assembly. Actual maximum static load may be reduced based on end machining and screw mounting hardware.

- **Dynamic Load –** The maximum recommended thrust load which should be applied to the lead screw and nut assembly while in motion.

- **PV Load –** Any material which carries a sliding load is limited by heat buildup caused by friction. The factors that affect heat generation rate in an application are the pressure on the nut in pounds per square inch of contact area and the surface velocity in feet per minute at the major diameter. The product of these factors provides a measure of the severity of an application.

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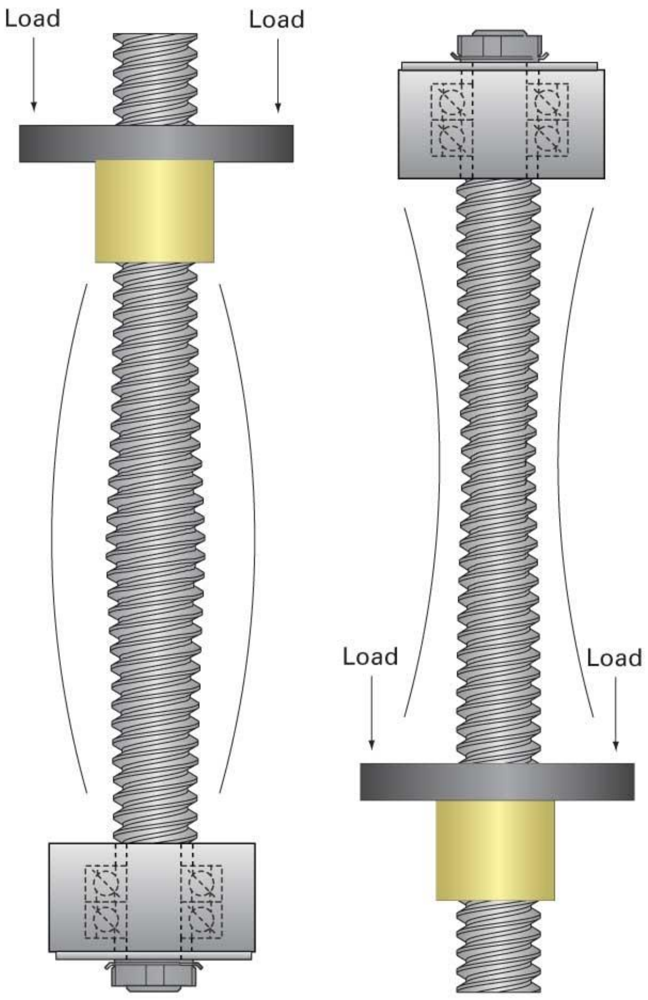
1. Load (continued)

- **Tension Load** – A load that tends to “stretch” the screw

- **Compression Load** – A load that tends to “squeeze” the screw



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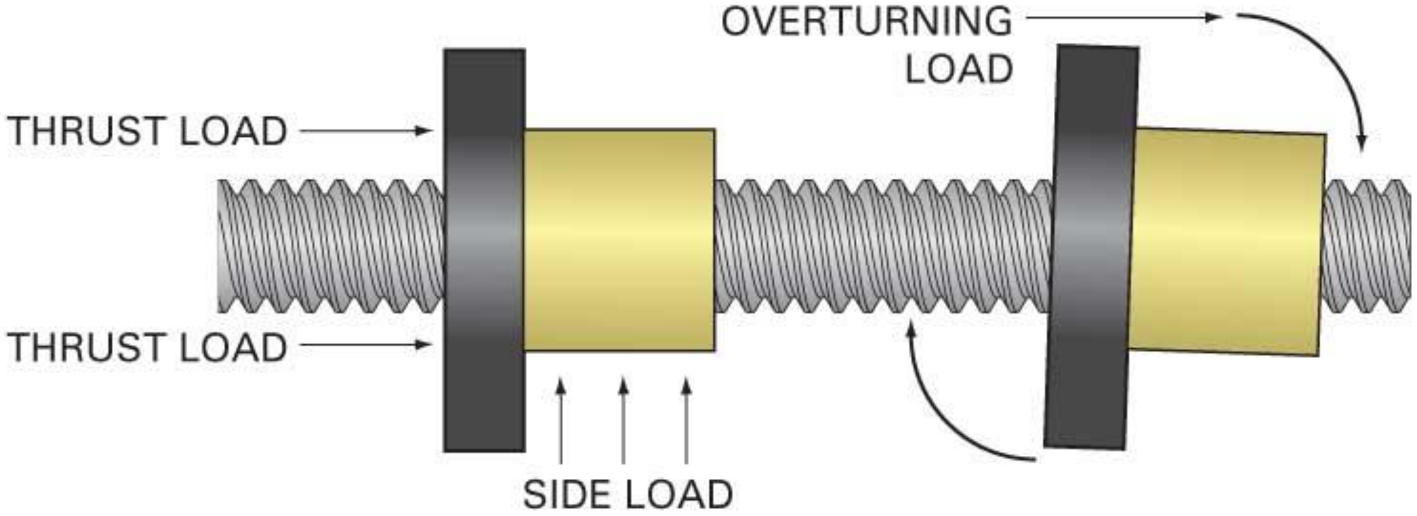
1. Load (continued)

- **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



2. Speed

The travel rate (linear speed) is the rpm at which the screw or nut is rotating multiplied by the lead of the screw.

3. Screw Inertia

Screw Size inch (mm)	Screw Inertia (oz-inch sec²/inch)
5/64 (2)	3.4×10^{-8}
1/8 (3.2)	1.8×10^{-7}
9/64 (3.5)	3.4×10^{-7}
5/32 (3.97)	4.9×10^{-7}
3/16 (4.76)	1.1×10^{-6}
7/32 (5.55)	1.8×10^{-6}
1/4 (6)	$.3 \times 10^{-5}$
5/16 (8)	5×10^{-5}
3/8 (10)	1.5×10^{-5}
7/16 (11)	3.5×10^{-5}
1/2 (13)	5.2×10^{-5}
5/8 (16)	14.2×10^{-5}
3/4 (19)	30.5×10^{-5}
7/8 (22)	58.0×10^{-5}
15/16 (24)	73.0×10^{-5}

4. Torque

The required motor torque to drive a lead screw assembly is the sum of three components:

1. **Inertial torque**
2. **Drag torque**
3. **Torque-to-move**

Please note that this is the torque necessary to drive the lead screw assembly alone.

Additional torque associated with driving frictional bearings and motor shafts as well as moving components and drag due to general assembly misalignment must be considered.

5. Inertial Torque

WHERE:

I = Screw inertia

α = Angular acceleration

$$\boxed{T_j = I\alpha}$$

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6. Drag Torque

Helix precision anti-backlash nut assemblies are typically supplied with drag torque of 1 to 7 oz.-in.

The magnitude of the drag torque is dependent on the standard factory settings or specified customer settings. Generally, the higher the preset force, the better the anti-backlash performance.

7. Torque-to-Move

$$T_L = \frac{\text{LOAD} \times \text{LEAD}}{2\pi \times \text{EFFICIENCY}}$$

8. Back Driving

Back driving (reversibility) is the ability of a screw to be turned by a thrust load applied to the nut. Often times, back driving will not occur when the screw lead is less than 1/3 the diameter for uncoated screws or 1/4 the diameter for Helix PTFE coated screws.

For higher leads where back driving is likely, the torque required for holding a load is:

$$T_b = \frac{\text{LOAD} \times \text{LEAD} \times \text{BACK DRIVE EFFICIENCY}}{2\pi}$$

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9. Length

The unsupported length of the screw between bearings measured in inches or millimeters.

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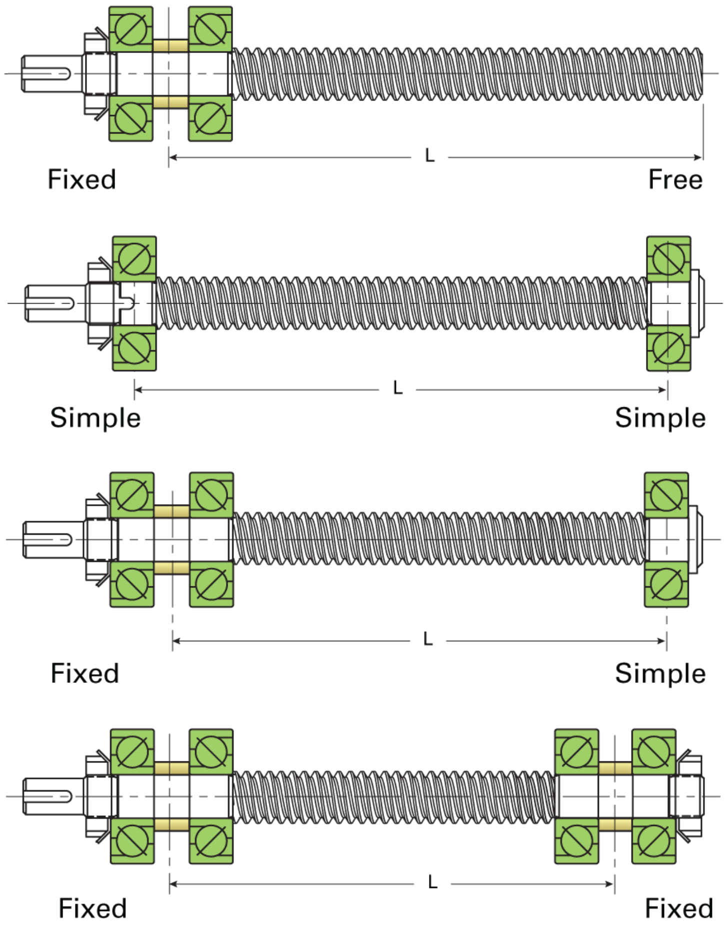
10. End Fixity

End fixity refers to the method by which the ends of the screw are supported. The degree of end fixity is related to the amount of restraint of the ends of the screw. Examples of the 3 basic types of end fixity are:

1. **Simple**
2. **Fixed**
3. **Free**

Simple End fixity can be provided through a single bearing support.

Multiple or Spaced Pairs of bearings are more rigid than a "Simple" support, but because of their compliance are not truly "Fixed."



CONSIDER:

Critical Speed

Once the load, speed, length and end fixity are identified, the next factor to consider is the critical speed. The speed that excites the natural frequency of the screw is referred to as the critical speed. Resonance at the natural frequency of the screw will occur regardless of the screw orientation (vertical, horizontal etc.) or if the system is designed so the nut rotates about the screw.

The critical speed will vary with the diameter, unsupported length, end fixity and rpm. Since critical speed can also be affected by shaft straightness and assembly alignment, it is recommended that the maximum speed be limited to 80% of the calculated critical speed.

CONSIDER:

Critical Speed (continued)

The theoretical formula to calculate critical speed in rpm is:

$$N = \frac{C_s \times 4.76 \times 10^6 \times d}{L^2}$$

The critical speed will vary with the diameter, unsupported length, end fixity and rpm. Since critical speed can also be affected by shaft straightness and assembly alignment, it is recommended that the maximum speed be limited to 80% of the calculated critical speed.

WHERE:

N = Critical Speed (rpm)
d = Root Diameter of Screw (inch)
L = Length Between Bearing Supports (inch)
C_s = 0.36 for one end fixed, one end free
1.00 for both ends simple
1.47 for one end fixed, one end simple
2.23 for both ends fixed

CONSIDER:

Critical Speed

If the selected lead screw does not meet critical speed criteria, consider the following options:

a) Increase screw lead and reduce rpm
b) Change end fixity (e.g. simple to fixed)
c) Increase screw diameter

CONSIDER:

Column Strength

When a screw is loaded in compression, its limit of elastic stability can be exceeded and the screw will fail through bending or buckling. The theoretical formula to calculate the column strength in pounds is:

$$P_{cr} = \frac{14.03 \times 10^6 \times F_c \times d^4}{L^2}$$

WHERE:

P_{cr} = Maximum Load (lb)

F_c = End Fixity Factor

0.25 for one end fixed, one end free

1.00 for both ends supported

2.00 for one end fixed, one end simple

4.00 for both ends rigid

d = Root Diameter of Screw (inch)

L = Distance between nut and load carrying bearing (inch)

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CONSIDER:

Column Strength (continued)

If the selected lead screw does not meet compression load criteria, consider the following options:

a) Change end fixity (e.g. simple to fixed)
b) Design to use screw in tension
c) Increase screw diameter

CONSIDER:

PV Value

For plastic nuts, the PV value needs to be checked. The operating load values for the plastic nuts are based on a pressure of 1,250 lb per square inch. Any loads less than the operating load can be evaluated by using the following formula:

$$P = \frac{\text{Actual Operating Load}}{\text{Chart Operating Load}} \times 1450$$

V is the relative speed between the nut and the screw in feet per minute. V can be calculated by using the following formula:

$$V = \frac{\text{Outside Dia. of the Screw (in)} \times \pi \times \text{Operating Speed (rpm)}}{12}$$

It is recommended that P × V be limited to values less than 2,700.

Consult HELIX to Determine the Right Lead Screw for You

For design engineers who have lead screw questions or need a lead screw that isn't standard, contact Helix. Whatever configuration you need, we can walk you through the process of specifying a lead screw that best fits your particular application.

To learn more about lead screws and HELIX options and capabilities, download our catalog.

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We hope you found this presentation helpful.

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