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Ball screw considerations

Screw drives are a popular mechanism to convert rotary to linear motion. A key characteristic of a screw drive is the lead or pitch which is how far the nut travels per revolution of the shaft. A small or fine lead increases the mechanical advantage compared to sprocket type drives. Fine leads have the added benefit of increasing the control precision in stepper or servo driven systems.

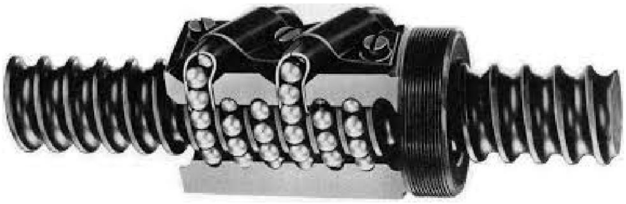
Screw drives that have plain surface contact between the nut and the screw are commonly known as lead screws, ACME screws or trapezoidal shafts. These are in effect a higher load version of a fastener with bronze commonly used to reduce friction in the metal to metal contact. A useful feature of these types of drives is in many cases they cannot be back driven and are self-locking. This does come at the cost of running efficiency and they are usually not suitable for continuous motion.

Wear rates of plain metal screws tends to be nonlinear and sensitive to lubrication temperatures and velocity. This makes for a highly variable service life and manufactures do not provide data for the life of plain bearing products.

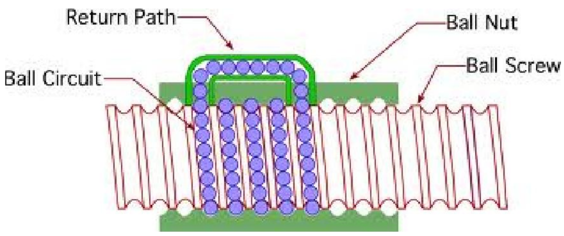

1 Ball screw


2 Trapezoidal screw

A ball screw replaces the metal to metal contact inside the nut with balls and provides a massive increase in efficiency usually above 90%. The balls roll between the precision worm of the shaft and the matching internal worm of the nut. Balls travel around circuits between the nut and shaft and are then recirculated by the nut in a similar manner to profile rail. The use of bearing steel s and rolling balls gives much higher consistency of service life across a wider range of applications and dynamic life is quoted by all reputable ball screw manufacturers.



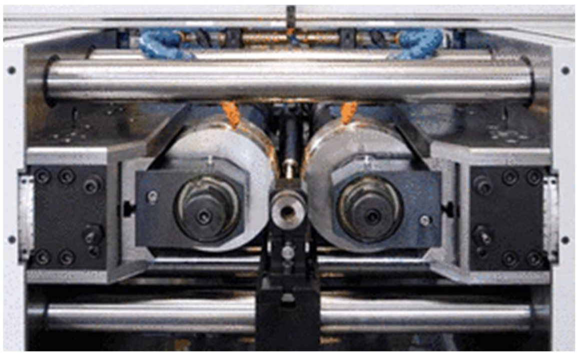
3 External Ball Return



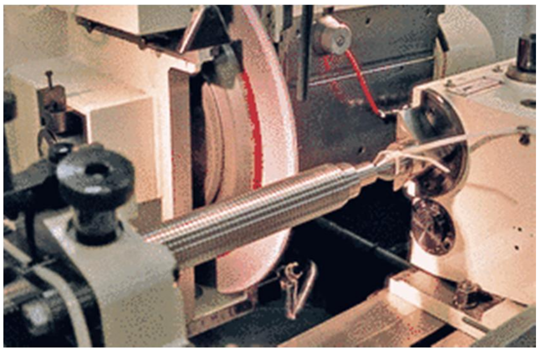
4 Recirculation schematic

There is a range of shaft size, leads and ball size available to give optimal performance for a range of applications. For example a precision CNC machine may use a large diameter small lead ball screw for high rigidity and mechanical advantage. Conversely a high speed production machine may use a high lead, large ball size specification for high dynamic performance and long service life.

The two main manufacturing methods for ball screws are grinding or rolling. Rolling is a more economical process where precision dies are used to form the threads. Precision rolled ball screws can have lead accuracy of up to ±0.023/300mm which is perfectly sufficient for industrial material handling equipment, general robotics and wood working machines. Grinding is a much more expensive process but gives accuracies as high as ±0.004/300mm with the added benefits of smoother surfaces and less pitch variation.

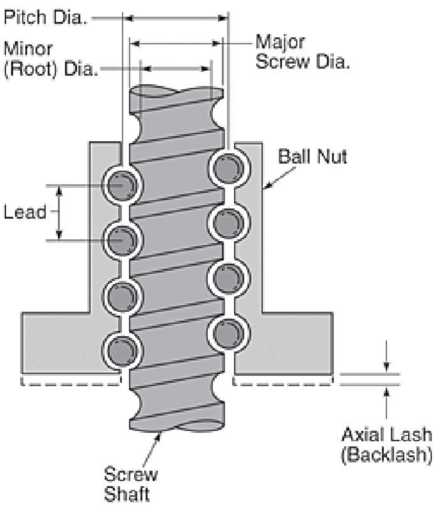


5 Rolling



6 Grinding

In some applications axial play or backlash needs to be considered. In order to be as free running as possible the balls will have a slight running clearance inside the nut. This will show up as a small amount of play or movement of the nut along the length of the shaft. In precision ball screws the amount of play can be barely felt by hand and is perfect acceptable in many applications. This is especially true in vertical applications where the load is almost always in one direction. Many modern motion controllers can compensate for backlash by parameter setting. The controller will increase the travel length when a motion is reversed to avoid "lost motion" or accumulated travel errors caused by the axial play.

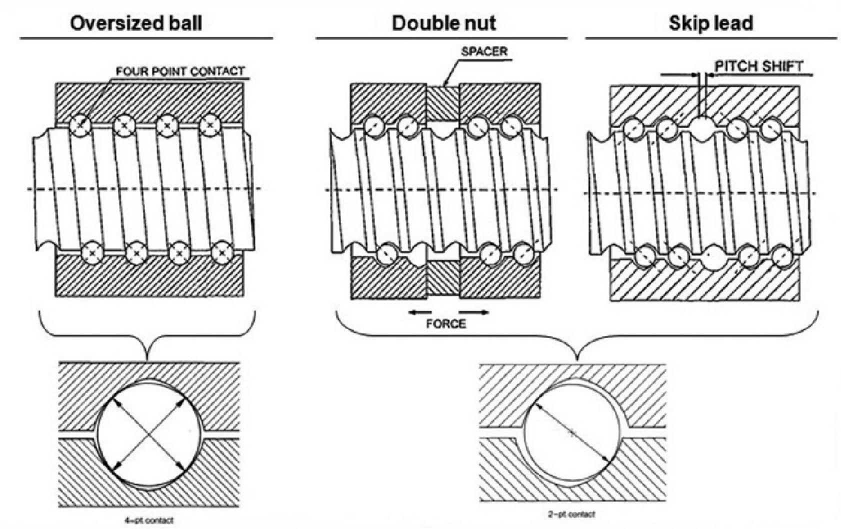


7 Backlash


8 Machining Chatter

Backlash can be more problematic in spindle machining operations. Reversing thrust loads occur as each tooth of the cutter contacts and releases from the work piece. Any play in the nut can cause movement in the axis compromising finish quality and accuracy. In extreme cases, where the rigidity of the work piece clamping and or the machine is low, vibrations at the spindle frequency can occur, a phenomenon known as chatter.

Backlash can be adjusted or eliminated in a number of ways. Adjustable double nuts are the ultimate for precision machining operations as they allow the preload to be adjusted on the machine to suit the rigidity and precision requirements. Small amounts of wear can also be adjusted in service. Offset or pitch shift preload can also be used where the circuits inside the nut are mirrored at the centre of the nut and offset slightly. The final method is to use oversized balls to eliminate clearance.



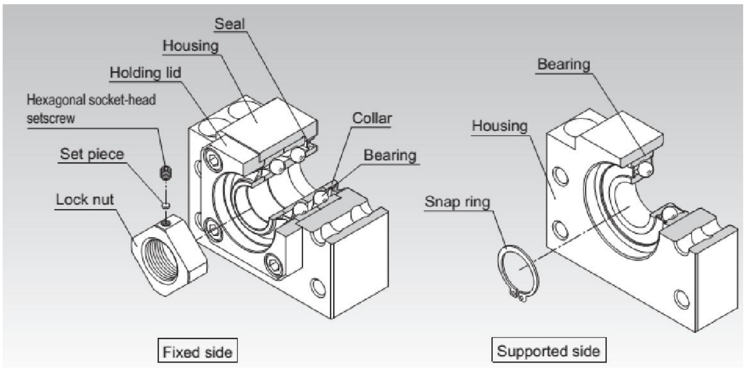
9 Backlash elimination methods

Supporting the shaft and nut in the mechanism must also be carefully considered in precision applications. Bearing journals and shoulders need to be coaxial with axial and radial run out minimised. The ball nut must only have thrust loads as radial or moment load will cause uneven loading of the balls within the nut. Inaccuracy of the end machining and nut mounting will reduce the life of the shaft and deflections can be reflected to the nut compromising running accuracy.

10 Journal Run Out

11 Fixed end journal machining

In applications where precision and accuracy are not a consideration then conventional deep groove bearings and shaft supports may produce acceptable performance. Where any precision is required face ground, paired DF thrust bearings and ground lock nuts need to be used. In the same manner as the journal machining play and run out of the bearings will have detrimental effects on the precision and service life. Precision shaft supports are available to meet the requirement of most applications.



12 Structure of shaft supports

13 Support styles

The environment and running conditions in service must also be considered. As in all ball bearing mechanisms lubrication is key to achieving a long service life. Wash off of lubrication and or contamination by particulates will compromise the ball screw. Dust protection, service and or lubrication should be considered during the design in high cycling critical applications. Where mechanisms cannot be completely isolated from damp or wash down environments then special treatments such as Raydent may be an option for corrosion protection.