NSK TECHNICAL INSIGHT

MBSA – Motorized Ball Screw Actuator

MECHATRONIC INTEGRATION FOR PRECISION MEDICAL DEVICE LINEAR MOTION

OPTIMIZING THE BALL SCREW AND MOTOR INTERFACE FOR COMPACT FORM, HIGH EFFICIENCY, AND POSITIONING ACCURACY

During the 21st century, our society has been at the forefront of discovering new solutions through advanced technology for medical device and clinical laboratory applications. These innovative solutions have utilized linear motion to develop stateof-the-art medical imaging, diagnostic and surgical equipment. Linear motion is a common need for all types of advanced equipment and machines; but precise, smooth, reliable, and repeatable linear motion is fundamentally important for several applications within the medical industry. Precision ground ball screws have become the preferred choice for precise linear motion because they deliver smooth and accurate movement ensuring reliable and repeatable results.

OVERVIEW

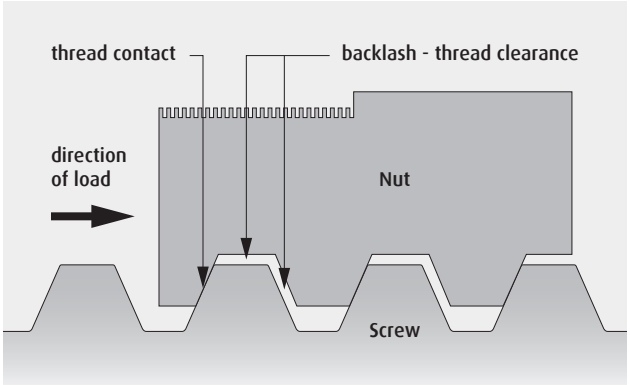
The demand to reduce the size of linear screw actuators, but maintain precision, is evident in several medical diagnostic and imaging applications. A diagnostic device, such as a desktop blood analyzer, can process multiple samples at a faster speed and higher accuracy in comparison to its predecessor that was the size of an automobile. Health care practitioners rely on small ball screw actuators on syringe pumps to accurately dispense precise levels of medication. In imaging applications, such as CT scanners, small actuators position aperture plates to control the X-ray beam. In each of these applications, a lead screw or ball screw is combined with a small electric motor to translate the motor's rotary motion into linear motion.

MBSA used in a Blood Analyzer

LEAD SCREWS VS. PRECISION GROUND BALL SCREWS

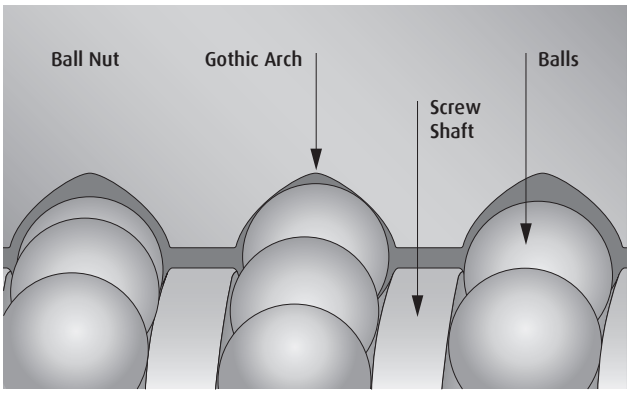
In order to achieve linear motion for medical applications, the traditional solution combines a lead screw with an electric stepping motor. Lead screws use a V-shaped helical thread on the shaft with a matching thread inside the nut, similar to a nut and bolt you can get at a hardware store. Lead screws (and ACME screws) rely on sliding contact between the surfaces of the nut thread and the shaft thread to produce linear motion.

The benefit of a lead screw is the small nut relative to the axial load it can support due to the large flat contact surface areas of the mating threads. However, the flat surfaces sliding across each other generate heat caused by friction. A large motor is required to overcome friction. As a result, this solution does not provide smooth consistent motion and will require more maintenance due to considerable wear. "Backlash" is inherent with the typical lead screw design caused by clearance between the nut thread and the shaft thread. The backlash affects the linear positioning accuracy of the screw. NSK understands the importance of minimizing or eliminating backlash and now offers an alternative solution.



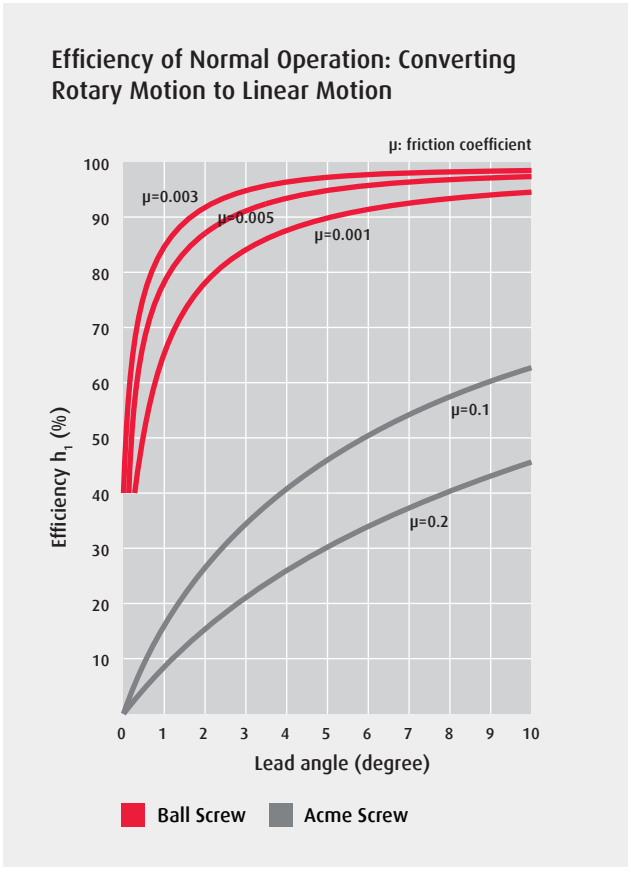
Lead Screw Nut and Shaft showing Axial and Radial Clearance

Regarded as the world's leading manufacturer of precision ground ball screws, NSK sought to integrate its precision ground ball screw into an electric stepping motor resulting in the new MBSA Series. Similar to a lead screw, a ball screw also has a helical thread on the shaft and inside the nut; but a ball screw uses precision ball bearings between

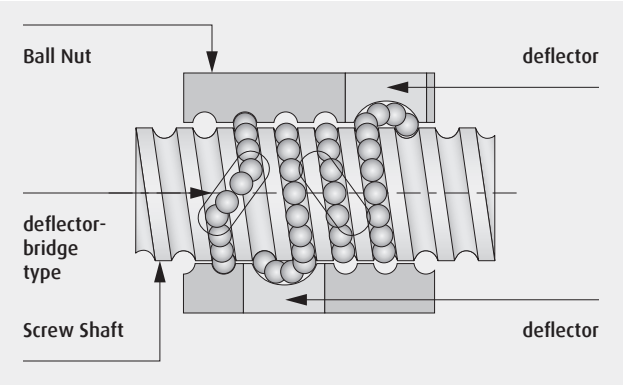


Precision Ground Ball Screw Gothic Arch Raceway

the nut and the shaft. Therefore the ball screw thread profile is different than that of a lead screw. The ball screw has a U-shaped groove, or Gothic arch, to house the precision ball bearings. The nut thread profile acts as the outer raceway and the groove along ball screw shaft acts as the inner raceway for ball bearing travel.



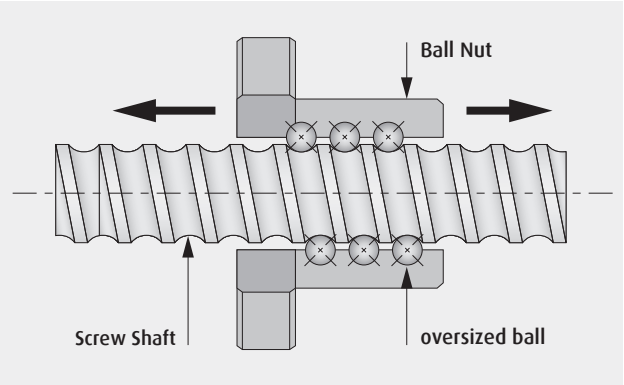
Ball Screw vs Lead Screw Efficiency



Deflector-Type Ball Screw

The ball bearings provide a rolling contact point between the nut and the shaft that lowers the coefficient of friction. The result is a highly efficient (90% to 95%) mechanism that requires less torque to convert rotational motion into linear motion making ball screws a better fit for the challenges inherent to medical applications. By using a precision ground ball screw, the application results in lower operating temperatures, smoother motion, reduced motor size, less energy consumed, less wear, and longer life in comparison to a lead screw solution.

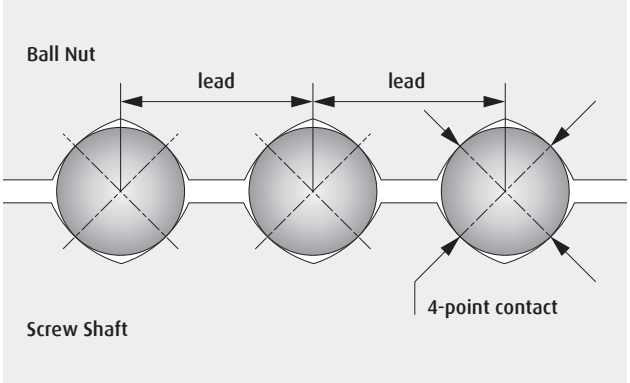
In order to adhere to small size constraints for the nut body, NSK uses a bridge-type deflector recirculation piece to guide the ball bearings between adjacent ball thread grooves or raceways providing the recirculation necessary for a ball screw. Since the deflectors sit below the surface of the nut body outside diameter, this area can be used as a pilot surface for instruments or components attached to the nut.



Ball Screw Preload using Oversized Ball Bearing

How To Prevent Backlash

To eliminate backlash or axial play between the screw shaft and the nut, NSK uses slightly oversized balls to create a light preload. The elastic deformation of the balls creates an internal force between the nut and the screw shaft to eliminate clearance. The result is precise linear movement of the object attached to the ball screw nut with zero backlash between shaft rotation and nut linear movement. This preload allows for better positioning control for medical applications with multi-directional axial loads.



Ball Screw 4 Points of Contact

High positioning accuracy is the result of a precision ground ball screw with a preloaded nut that eliminates backlash. Lead accuracy is measured by calculating the difference between the actual linear distance traveled by the ball screw nut in one shaft revolution versus the theoretical distance traveled (equal to the lead). The International Organization for Standardization (ISO) has set lead accuracy standards for precision ball screws. To conceptually visualize the accuracy, the average human hair is 0.080mm in diameter. For the MBSA Series, NSK uses a C3 accuracy ball screw which has a lead accuracy of 0.006mm per shaft revolution. The stepping motor paired with the ball screw has 200 counts per revolution resulting in a motor resolution of 0.005mm for a 1mm lead ball screw. When measuring lead accuracy over 300mm (or 1 foot) of travel, the actual nut position deviation from the theoretical nut position is a maximum of 0.008mm for a C3 accuracy ball screw. Comparatively, a lead screw can have a deviation as large as 0.250mm in 300mm of travel. Therefore the MBSA Series is the optimal solution for highly precise medical devices and laboratory equipment.

NSK

Integrating Ball Screws And Motors

In the development of the MBSA Series, NSK replaced the electric motor output shaft with a journal that is part of the ball screw shaft. The motor directly rotates the ball screw shaft which translates the nut for linear motion. This design eliminates the need for a separate motor-to-ball screw coupling. The MBSA Series allows for a compact space-saving design that reduces system inertia and eliminates alignment error that can occur when the motor and ball screw are separately mounted. This new product series is small enough to fit in the palm of your hand.

The MBSA Series is also designed to accommodate a configurable encoder mounted to the back of the stepping motor. The stepping motor can communicate with a wide variety of controllers/drivers. Customers may customize by selecting the controller/driver of their choice.

Sizing And Availability

As our world continues to evolve, medical devices and laboratory equipment used in diagnostics, syringe pumps, microfluidics, imaging, cancer treatment, and other applications requiring automation will benefit from these types of integrated solutions. To learn more about how NSK's MBSA Series can ensure precise, reliable and repeatable movement for your medical application, contact us (1.888.446.5675) or visit our website (nskautomation.com).

NEMA14 MBSA with Optional Encoder and Support Bearing Installed

STANDARD MBSA SCREW SHAFT / MOTOR MODEL COMBINATIONS								
SHAFT DIAMETER		06		08				
STEPPER MOTOR		NEMA 14		NEMA 14		NEMA 17		
SHAFT LEAD		1	2	1	2	1	2	
THREADED SHAFT LENGTH	50	■	■	■	■	■	■	
	100	■	■	■	■	■	■	
	125	■	■	■	■	■	■	
	150			■	■	■	■	
	200				■		■	

■ Shaft Diameter / Stepper Motor / Shaft Lead combinations available from stock.
For additional combinations, please consult NSK.