Avoid Ball Screw Failure Through Proper Design and Maintenance

Ball screws are used in linear motion applications across many industries. They are one of the most economical ways of converting rotary motion into precision linear motion and can move heavy loads at fast speeds with outstanding accuracy. While these devices provide numerous hours of smooth, trouble-free operation, they must be properly designed, installed, and regularly maintained to avoid system downtime and premature failure.

This account reviews the various ball screw failure modes and describes how Rockford Ball Screw (RBS) can assist with ball screw system design, maintenance, repair, and replacement.

Ball screw overview:

Ball screw assemblies consist of a screw that is driven by a rotary motor, a ball nut with recirculating bearings, attached to a translating carriage and thrust bearings on one or both ends of the screw to support axial loads and define alignment (Figure 1).

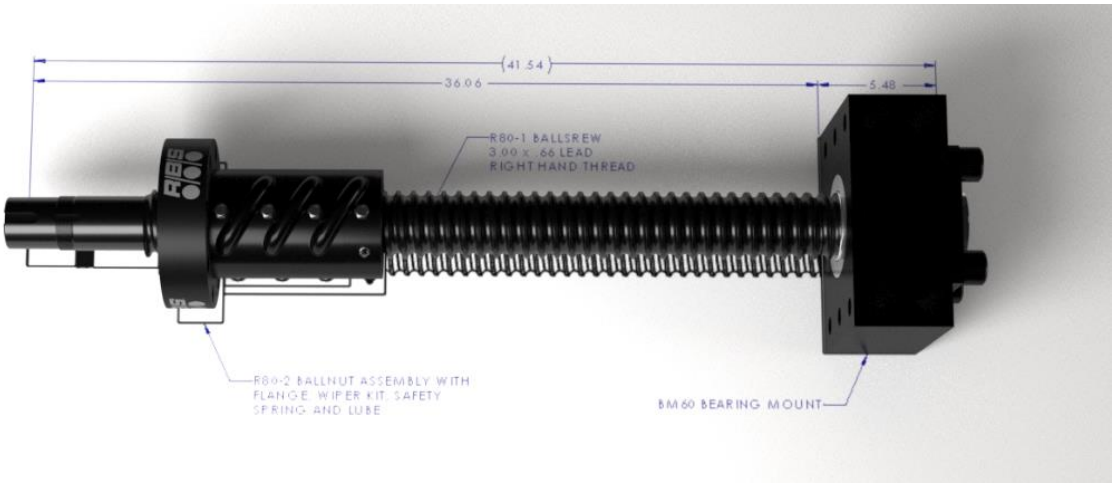

Figure 1. Ball screw components. Source: RBS

In a properly operating ball screw system, the motor turns the screw, which enables the nut to linearly translate along the length of the screw. Recirculating ball bearings maintain intimate contact between the nut and the screw to ensure a highly efficient movement, allowing precise positioning of the translating nut. Inertial forces encountered by acceleration/deceleration of the carriage are reacted through the thrust bearings on one or both ends of the screw.

The failure of ball screw components can result in numerous effects. First, the ability of the system to precisely control the position of the carriage becomes compromised through excessive backlash or vibration. Eventually, the torque required by the motor to turn the screw can increase to the point where catastrophic failure occurs, and the ball screw is no longer operational. This can cause significant system downtime to repair or replace worn or damaged components.

Regular preventive maintenance (PM) of the ball screw system can ensure reliable, trouble-free operation. Ball screw components must be cleaned to remove debris and old lubricant residue and then replenished with new lubricant. The frequency for ball screw maintenance is determined by the duty cycle requirement and environment in which the ball screw operates. More frequent inspections after installation and startup are recommended to monitor cleanliness, alignment, and smooth operation. These checks should be incorporated into the overall device preventative maintenance schedule.

Ball screw failure mechanisms

Potential ball screw failure mechanisms include the following:

Insufficient lubrication - Ball screws are selected for an application to provide a smooth, highly efficient transmission of rotary motion to linear power. To do this, the relationship between the ball nut and ball screw must maintain a low friction environment. The ball screw assembly design utilizes lubrication to create a minimization of rolling resistance between balls and grooves along with a reduction of the sliding friction between adjacent balls. Lubrication (grease or oil) minimizes friction, reduces torque, increases a ball screw assembly's efficiency, and extends its life. When ball screws go without scheduled lubrication, a grinding metal-to-metal contact event occurs. This normally results in unanticipated downtime. Operating temperature, duty cycle, environment, axial load, and RPM/speed determine the lube application rate needed for each installation.

- General lube type suggestions:
  - Light loads and high speeds - machine oil or low viscosity grease.
  - Medium loads / speeds - NLGI 1 or 2 grease.
  - High loads - grease with an EP2 additive. The EP is Extreme Pressure, prevents the grease from breaking down.

Excessive heat — For applications having elevated temperature operating conditions, it is recommended that a high temperature-rated lubricant be used that resists oxidation and evaporation. If a lubricant is not rated for high temperatures it can oxidate, evaporate or run off leaving the ball bearing contact surfaces dry.

Dirt or contamination — The accumulation of dirt or debris can lead to clogging of the ball return circuits or wear of the contact surface. Chemical exposure can also contaminate a ball screw by stripping away the lubricants and attacking the contact surfaces, resulting in oxidation or corrosion. When the operating environment is dusty or creates chips, the use of wipers or end seals are recommended to prevent debris getting into the ball nut. Bellows, way covers or other types of guarding may also be required to prevent accumulation of debris on the ball screw and help keep debris away from the ball nut. Regular cleaning of the ball screw and replacement of lubrication is critical for avoiding this type of failure.

Incorrect alignment — The ball screw must be installed in a manner to ensure proper alignment with the guiding system to avoid generating bending moments or binding during travel. Ball screws are designed for axial loading only, so non-axial loads will create bending moments on the ball nut, reducing life and eventually seizing up ball nut motion. The use of precise measurement equipment, such as dial indicators, can confirm alignment of the nut over the entire length of the screw.

Insufficient ball recirculation — Short back and forth stroking or dithering movements of a ball screw will cause loading to be concentrated on one area of the ball screw and the same ball bearing surfaces, causing lubrication to be displaced and brinelling of the surfaces. Eventually the ball bearings will deteriorate and will not be able to properly roll, eventually seizing up ball nut motion. Periodic longer-travel strokes are therefore recommended that will allow the ball bearings and lubrication to fully recirculate.

System under-rated for application — Overloading a ball screw will reduce life, so it must be sized or rated properly for a given application. Several factors affect sizing, including the maximum load being moved, its travel rate or speed, the critical ball speed, column load, duty cycle, end fixity and drive torque. Whether the nut is in compression or tension, vertical versus horizontal orientation, other factors can include the operating environment, system mounting, stroke length and load guidance.

Excessive speed — The critical ball speed defines the maximum speed at which the balls may move through the ball nut without causing rapid ball deterioration. Furthermore, running the ball screw at or above the critical shaft speed will generate resonant vibrations that can cause system misalignment, control issues, positioning accuracy loss and premature failure of the end support bearings and/or drive system. It is very important to ensure the required load travel rate is within the rated critical ball screw and ball nut ball speeds to avoid these types of failures.

Rockford Ball Screw

RBS has been an industry leader in ball screws and linear guide rails since 1973. Their products are made in the U.S. with a state-of-the-art manufacturing facility in Rockford, Illinois that is ISO 9001 registered, and dedicated to high quality and continuous improvement. RBS products include metric and imperial ball screws, free-wheeling ball screws, ACME screws, bearing supports and linear guide rail systems (Figures 2 and 3, below).

Rockford has one of the highest services-to-client ratios in the industry with professional sales, application engineering and design engineering staffs that provide personalized customer service by providing guidance to customers in selection of appropriate off-the-shelf ball screw systems, assisting customers in design and development of new or custom ball screw systems, evaluating existing or obsolete ball screw systems and retrofitting systems with more modern and reliable technology and providing after-sales repair and maintenance of ball screw systems.

More information about the company's products and services can be found on the RBS website.

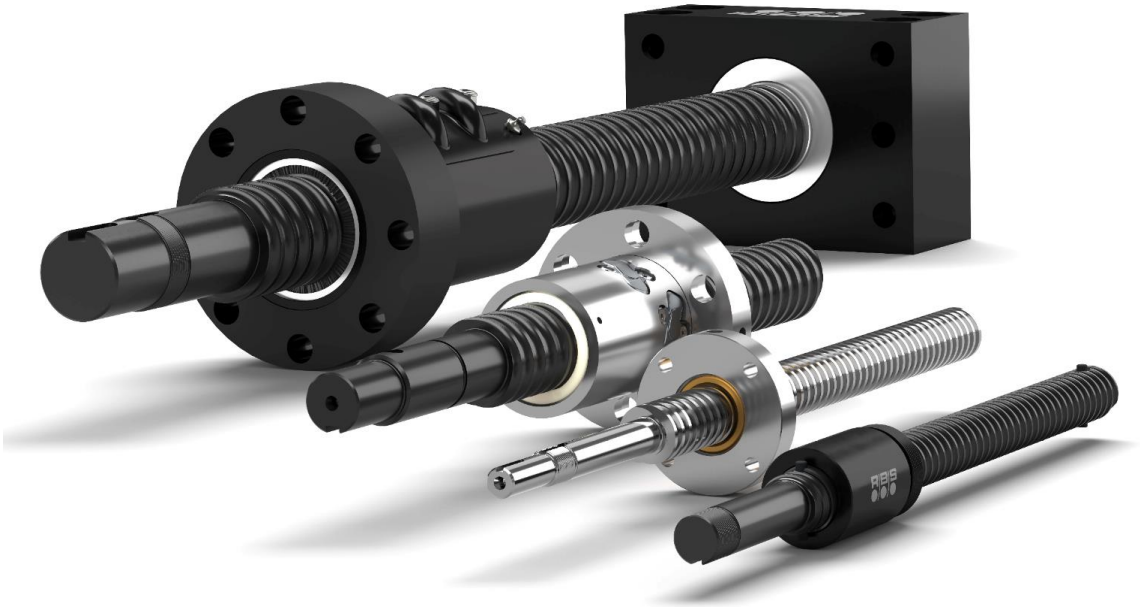

Figure 2. ROCKFORD BALL SCREW ball screw products. Source: RBS

Figure 3. ROCKFORD BALL SCREW linear guide products. Source: RBS