

“Optimizing Bearings for Gearboxes”

by Jamie Collins and MaryAnn Houghton

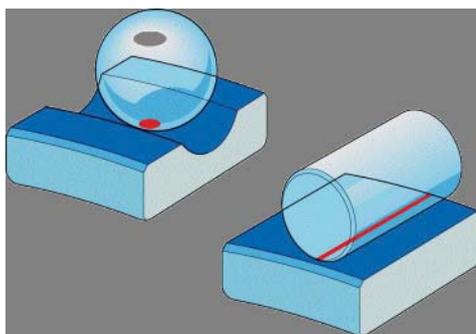
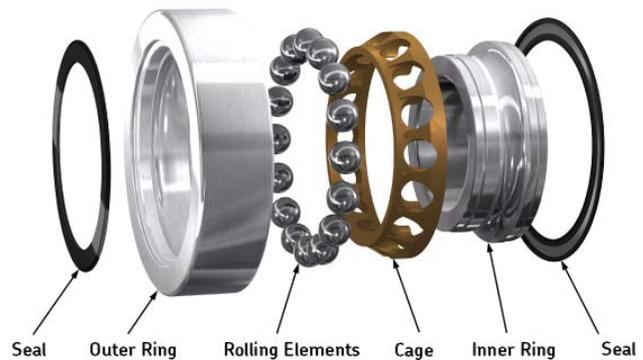
Bearings are a crucial component in machines that make things work, from dentist’s drills to wind turbines. They range in size from tiny bearings that would fit over the diameter of a pencil to large bearings that would fit over the diameter of a car. In the middle, however, are bearings most commonly used in gearboxes. Gearboxes are the work horses of manufacturing.

A bearing’s primary function is to reduce friction and transmit loads between rotating and stationary components. Additionally, they are used to support and locate shafts. When choosing the type of bearing for a given application, one must identify how the bearing will be used and the loads that will be applied to it. These factors and more must be considered when selecting the correct bearings for a gear reducer.

How does one go about selecting a bearing for an application? What elements are in a bearing? What types of loads can the bearing handle? What calculations should be done? This whitepaper will answer those questions and more.

Bearing Elements and Types

A bearing is comprised of several key elements which include: an inner ring, an outer ring, cage, rolling elements, seals, and lubrication. Varying the design and materials of these components can greatly impact the performance of the bearing in an application.



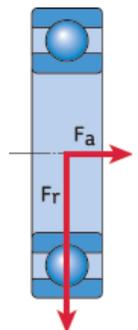
The red area is the contact point.

Various bearings are designed to carry loads differently. Two key types of bearings are ball bearings and roller bearings. Ball bearings have a contact point that concentrates the load carried by the bearing in one small area (see red area in picture). These bearings are excellent for higher speed applications with light loads. Roller bearings have rolling elements that are elongated, which create a line contact within the bearing. Roller bearings have lower speed limits but are able to carry a significantly large load.

Loads

Many bearing families are considered to be good for handling radial loads (F_r), axial loads (F_a), or a combination of radial and axial loads. Cylindrical roller bearings, for example, are designed to handle radial loads and can handle some very limited axial loads.

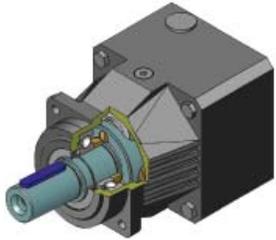
If the maximum axial load recommendation on a cylindrical roller bearing is exceeded, the side of the rolling element will rub on the ring side flange, increasing bearing friction and creating higher temperatures. If the axial load is significant, wear can occur on the roller end



and the flange. Bearings such as the angular contact ball bearing or taper roller bearing are designed to handle axial loads, making them a better choice for high axial load applications. These factors must be taken into consideration when selecting the correct bearing combination for a gearbox.

Options

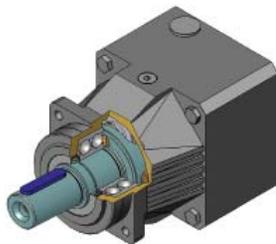
Some manufacturers offer different bearing options depending on the application.



Deep Groove Ball Bearing

Generally used in applications with:

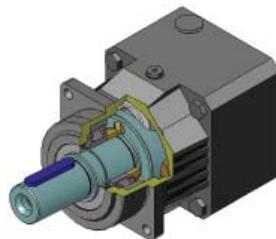
- couplings,
- belts with or without light tension,
- spur geared rack and pinion.



Double Row Angular Contact Ball Bearing

Typically used in applications with:

- helical geared rack and pinion,
- couplings with high axial load,
- belts with or without light tension.



Cylindrical Roller Bearing

Commonly used in applications with:

- pre-stressed belt drives,
- pre-stressed spur rack drives,
- high radial loads,
- high service requirements.

Bearing Life

When selecting a bearing for an application, the shaft speed, load conditions, operating temperature, and preferred lubricant should be considered in addition to the space available to place the bearing.

The theoretical life of a bearing is influenced by many application factors. In 1947, Lundberg and Palmgren developed the basic life (L_{10}) calculation that considers the application equivalent dynamic bearing load (P), the dynamic load rating (C), and a factor (p) determined by the type of bearing.

$$L_{10} = \left(\frac{C}{P} \right)^p$$

The theoretical L_{10} bearing life is the calculated life that 90% of a given population of bearings will meet or exceed. The basic L_{10} calculation has limited factors that contribute to the theoretical life calculation. To have a more precise life estimate, additional factors need to be considered. The SKF Rating Life builds on the L_{10} life calculation with an a_{SKF} factor.

$$L_{10aa} = a_{SKF} \left(\frac{C}{P} \right)^p$$

The a_{SKF} life adjustment factor takes into account lubrication, contamination, and the fatigue stress limit.

Higher level computer programs can calculate a more precise estimate of bearing life. Due to the precision and sensitivity of the iterative calculations, the accuracy of the application factors input into the program becomes essential.

Damage Sources

Bearing damage can be caused by a number of reasons. The top sources of early bearing damage include inadequate lubrication and fatigue. Bearing fatigue is caused by repeated stresses in the contact areas between the rolling elements and the raceways. Repeated stress and material structural changes can lead to spalling.

According to the ISO classification system of bearing damage, spalling is the development of micro-cracks under the bearing surface and can lead to crack propagation. It is also known as flaking and peeling. The spalling of particles from the contact surfaces is a visible sign of bearing fatigue and can lead to additional bearing damage.



Damage from spalling

In addition to spalled particles, external contamination can damage bearings. Some manufacturers provide magnetic drain plugs to help remove the metallic particles from the lubricant. These particles, even those smaller than a human hair, can interrupt the lubrication

film within the bearing. With the lubricant film being disrupted, contact between the metal components of the bearing can occur. Contaminate particles can create dents on the rolling elements and the raceways. Dents are stress raisers which may speed up the fatigue process.

Damaged bearings may become noisier or see a thermal increase as the damage worsens. Therefore, keeping bearings clean is critical to maximizing bearing life. Using sealed gearboxes can prevent oil contamination from outside particles.

Lubrication

For bearings to properly function, adequate lubrication is needed to prevent metal to metal contact between the rolling elements, raceways, and cages. Separation of the surfaces in the bearing is the primary function of the lubricant, which must also inhibit wear and protect the bearing surfaces from corrosion. In some applications, the lubricant is also used to carry away heat.

Lubrication of a bearing can be achieved through several methods. Grease and oil are the two main types of lubrication. Oil can be applied in a variety of ways including oil bath, circulating oil, oil mist, oil jet, and oil spot.

The effectiveness of a particular lubricant is determined by the viscosity ratio κ (kappa). Kappa is the ratio of the actual operating viscosity v (at operating temperature) to the required kinematic viscosity v_1 . When $\kappa \geq 1$, the rolling contact surfaces in the bearing are separated by a minimum lubricant film. Ideally, a $\kappa \geq 2$ is used to help ensure good separation. The continued separation of the contact surfaces in a bearing can extend the theoretical life. Temperatures that differ from the design specifications and contamination can reduce the effectiveness of a selected lubricant, reducing the life of a bearing.

Some bearings are manufactured with integral seals or metal shields. These bearings are not relubricatable and the life of the bearing is often limited to the life of the grease in the

bearing. Bearings without seals and shields are considered to be open bearings. Open bearings must be lubricated at assembly and periodically re-lubricated. Application specific amounts of fresh grease can be added, increasing the potential life of the bearing. If re-lubrication does not occur, eventually the grease will oxidize and not perform as required.

Conclusion

Bearing life in gearboxes can also be extended when a one piece housing gearbox is used. One piece housings mean one center line. It prevents misalignments of the bearing, reducing preload pressures. These gearboxes also are more efficient, durable, and have an overall longer life compared to units with multi-piece housings.

When properly selected and applied in a gear reducer, bearings will give years of worry-free service. If the bearings are further maintained according to the manufacturers' guidelines, the bearing life can be even greater. Always make sure to use the correct lubrication to avoid damage to your bearings.

Ultimately all of these elements add up to affect the overall life of your gear reducer. If you properly select a gearbox with the correct bearings for your application, you will be rewarded with a solution that will give you a long life while avoiding unnecessary downtime from premature bearing failures.

Jamie Collins
STOBER Drives, Inc. • Maysville, KY
us.stober.com • 800-711-3588



MaryAnn Houghton
SKF Industrial Drives • Lansdale, PA
www.SKF.com • 1-267-436-6000

