Stuart F. Brown

Selecting the right lubricant for rolling element bearings

Viscosity, grease, temperature and oil versus grease are key factors to consider when making your decision.

KEY CONCEPTS

- The ideal operating condition for a bearing is elastohydrodynamic lubrication where any contact between metal surfaces is prevented by the lubricant.
- When selecting oil viscosity, consider the mean diameter of the bearing in millimeters, operating speed in rpm and the temperature of the system in Celsius.
- Five common systems deliver oil to bearings: static oil baths, oil ring pickups, circulating oil systems, oil mist systems and oil-plus-air systems.

PROPER LUBRICATION MEANS EVERYTHING FOR A ROLLING ELEMENT BEARING, whether its contact surfaces are metal balls or metal rollers. Both types of bearings have rolling-contact and sliding-contact surfaces that are held apart from each other by a thin film of lubricant that becomes highly pressurized from the load applied. The lubricant prevents metal-to-metal contact, which would quickly cause damage to the bearing's highly finished working surfaces.

This article is based on information adapted from an STLE University Webinar originally presented on Sept. 23, 2014, by Jim Oliver, director of application engineering at SKF Bearings USA, Inc.

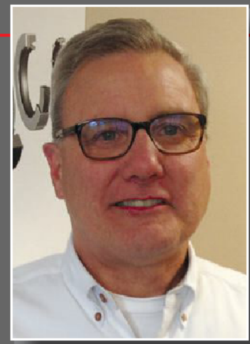
The ideal operating condition for a bearing is a state called elastohydrodynamic lubrication *(see Figure 1)* where any contact between metal surfaces is prevented by the lubricant as it is forcefully squeezed through the slender gap between the rolling components. During its brief passage through the gap, the lubricant's pressure increases to 40

 Despite the hard quality of the stone of the head, the face is badly damaged and not only by natural erosion.

MEET THE PRESENTER

This article is based on a Webinar originally presented by STLE University. "Lubrication Selection for Rolling Element Bearings" is available at **www.stle.org:** $39 to STLE members, $59 for all others.

Jim Oliver obtained his bachelor's of science degree in mechanical engineering from Lafayette College in May 1985 and began his career with SKF immediately afterward. During Jim's career at SKF he worked as an application engineer, sales representative, service manager and application engineering manager for SKF's industrial market. In December 2014 he was appointed vice president of SKF Engineering. He enjoys fishing, sailing and woodworking. You can reach Jim at **james.a.oliver@skf.com.**



James Oliver

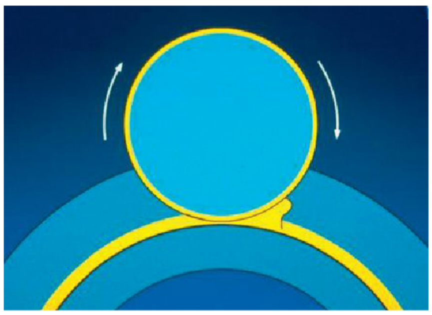


Figure 1 | **The ideal operating condition for a bearing is a state called elastohydrodynamic lubrication.**

times the pressure of water at the bottom of the sea, sufficient to briefly distort the metal components while still preventing injurious contact between them. At these terrific pressures, the lubricant momentarily becomes a semi-solid with a cheese-like consistency.

Once past the gap, the lubricant reverts to its inherent viscosity, or resistance to flow. To put viscosity in perspective, water has a very low viscosity of 1 centistoke, a unit for measuring kinematic viscosity. Honey, which everyone knows is much thicker than water, has a very high viscosity of about 1,200 centistokes by comparison.

Viscosity is a key characteristic for choosing the right lubricant for a rolling element bearing. Increasing the lubricant's base oil viscosity increases the thickness of the lubricant film, permitting the engineer to keep bearings operating in the desired elastohydrodynamic state where metal surfaces are not allowed to touch one another.

How do we know when we have adequate viscosity? We use a ratio called kappa, or the viscosity ratio. The kappa value is the required viscosity of the lubricant at operating temperature in relationship to actual viscosity at operating temperature. As the kappa value increases, there is greater viscosity in the bearing, so we should get more separation of the rolling element surfaces.

In hydrodynamic lubrication, a ratio greater than two is desirable. Between ratios of 2-4, we'll have a full oil film, total rolling element separation and good hydrodynamic lubrication (*see Figure 2a*). At a ratio of greater than four, returns begin to diminish as frictional and viscous drag created by the lubricant generates heat, which has the undesirable effect of decreasing the operating viscosity.

Often calculations end up in the mixed-film area where kappa values run from 0.4-2.0 (*see Figure 2b*). This can be the case under very highly loaded operating conditions. In such cases, we would probably use an extreme pressure (EP) additive in the lubricant. Similarly, if we are in the boundary lubrication regime where the gap is incomplete and kappa is lower than 0.4, EP additives must be used (*see Figure 2c*).

When selecting oil viscosity, three key factors are used by the bearing application engineer. The first one is the mean diameter of the bearing in millimeters. The second criteria is operating speed in rpm. The third factor is the actual temperature of the system in degrees Celsius. We may also look at the environment. Is it hot, dirty or cryogenic?

Grease or oil?

Once we have the base oil viscosity properly selected, another decision looms: Which lubricant will work better, grease or oil? Oliver says, "As it turns out, about 80% of all the bearings

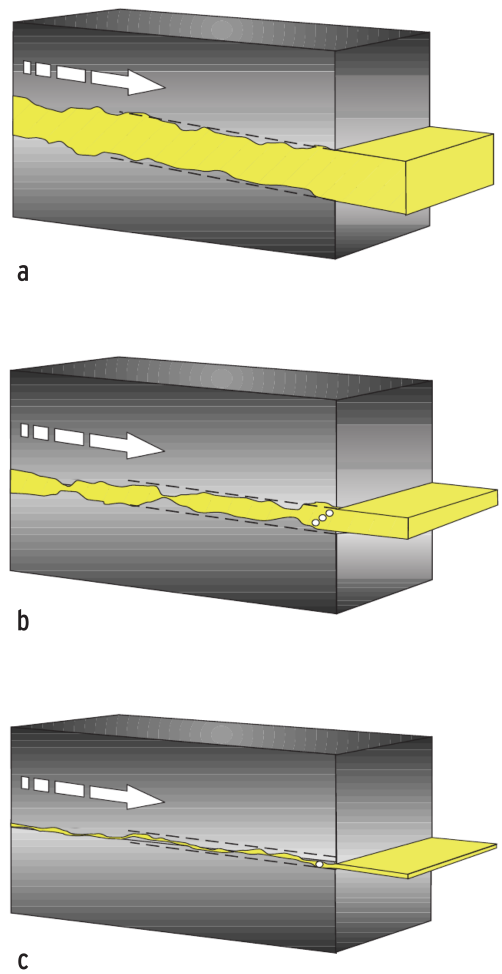


Figure 2 | **(*a*) Hydrodynamic lubrication, (*b*) mixed-film lubrication and (*c*) boundary lubrication.**

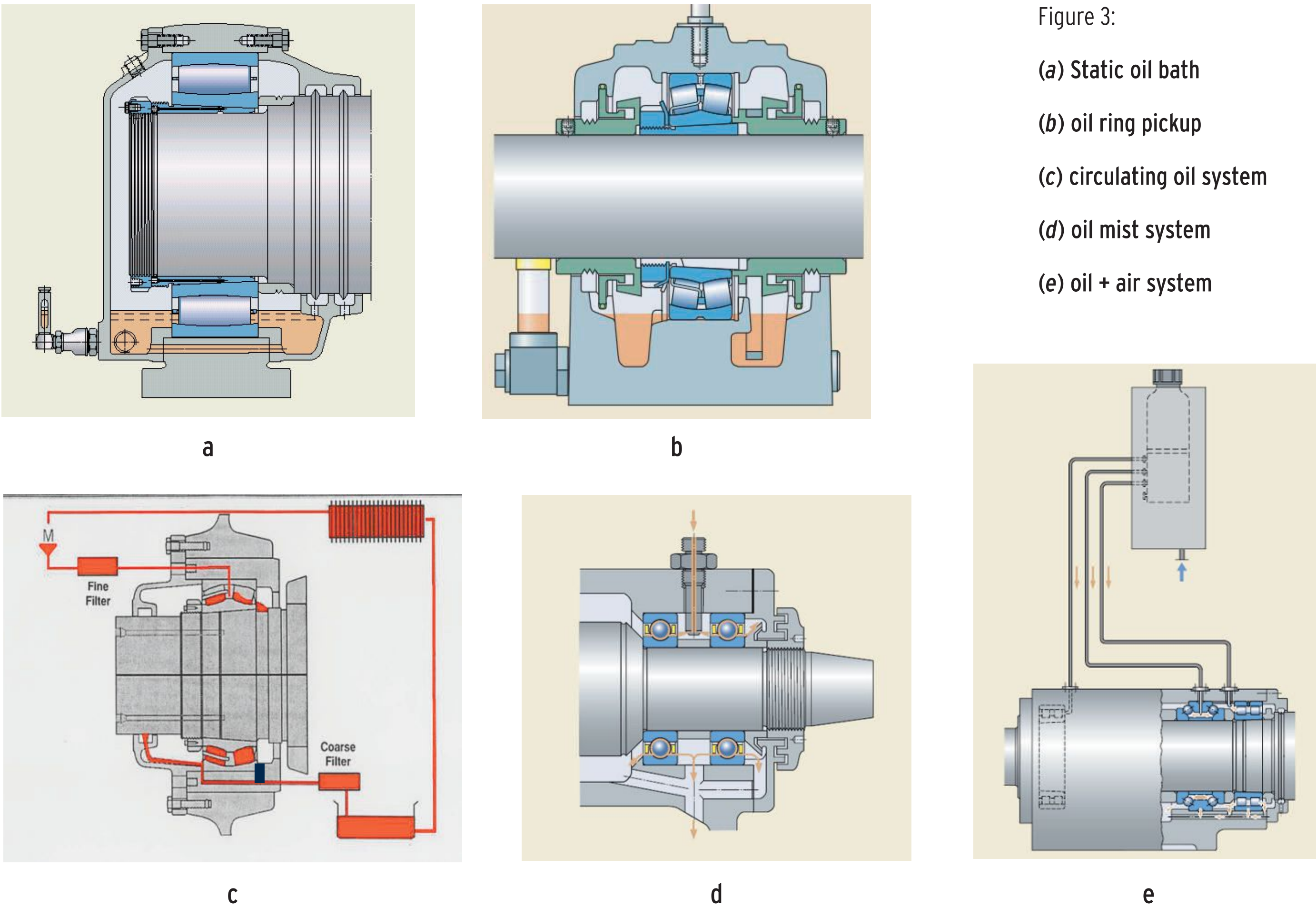


Figure 3:
(*a*) Static oil bath
(*b*) oil ring pickup
(*c*) circulating oil system
(*d*) oil mist system
(*e*) oil + air system

in service are grease lubricated. This is because grease is easy to apply and maintain. And cleanliness improves with the use of grease because the lubricant isn't likely to leak all over the place, as oil can do."

Oil comes into its own as a lubricant when operating temperatures reach a high of around 93.3 C (200 F). Oil also wins when bearing operating speeds are at or above the maximums shown on application charts. Oil used in rolling element bearings is almost always of the mineral type, or made with a synthetic polyalphaolefin.

No fewer than five common systems are in use for delivering oil to bearings in working machinery. (*see Figure 3*). They are static oil baths, ring pickups with a slinger that throws oil onto moving parts, circulating oil systems, oil mist systems and oil-plus-air systems.

A static oil bath can be used at higher speeds and operating temperatures and dissipates heat better than grease does. Such systems also provide less viscous drag and churning of the oil bath. A disadvantage is a heat-producing churning effect if the oil is kept above the recommended maximum fill level.

Oil ring pickup systems are commonly used in pumps and gearboxes. They can create less friction than the oil bath type because the bearing elements are not constantly splashing through the oil. Shortcomings include not carrying heat away from the system and not continuously supplying fresh oil.

Circulating oil systems lubricate the bearings while also taking heat away from them. Circulating systems continuously supply regulated amounts of oil, which can be cooled by a heat exchanger on its way back to the oil reservoir. Oil flow also can be passed through a filter to remove particulate matter from the liquid. A disadvantage is that these systems can be pretty large and present packaging challenges.

Oil-mist lubricating systems are very effective and efficient. Fresh oil passes through an orifice and is atomized on its way to the bearings. A vent on the opposite side of the device from the misting nozzle creates a pull-through effect that deposits a light coat of oil on the components, while creating very little viscous drag. A messiness factor is due to the tendency of escaped oil mist to coat nearby equipment in the work area.

Finally, oil-plus-air lubricating systems have been finding applications over the past 15 years or so. The oil in these systems is not atomized but rather delivered drop by drop to a stream of air flowing in a tube. The drops cling to the tubing walls and are transformed by the rushing air into streaks that form a continuous flow of oil for delivery to

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Figure 4 | **Grease is actually 85%-90% oil, suspended in a thickener. Grease or oil selection criteria include speed, ambient temperature, bearing operating temperature and environment.**

a bearing's lubrication point. Both oil mist and oil-plus-air lubricating systems are effective in bearings turning at very high speeds and thus are often used in machine tool spindles.

Although we may think of it as a separate unique substance, grease is actually 85%-90% oil, suspended in a thickener (*see Figure 4*). When selecting a grease, we first determine the desired base oil viscosity, which will determine the oil film thickness. Next we look at the stiffness or consistency of the grease—how stiff and thick it is. Then we will take a look at any additional lubricant properties required to determine the thickener and base oil type. Finally, determine any additives needed in the base oil such as EP or other additives like antioxidants or antifoaming agents.

Grease stiffness is determined by the National Lubricating Grease Institute (NLGI). Grease used for rolling element bearings is rated at NLGI stiffness grades 1, 2 or 3, with 2 being the most common. Oliver says, "There is a difference between viscosity and consistency, terms that are commonly misunderstood. Just because a grease is thick does not mean that it has a high oil viscosity. And just because it's thin doesn't mean it's got a low oil viscosity."

Viscosity measures the lubricity of the base oil, how it flows. The base oil forms the oil film separating the bearing surfaces. Consistency is the ability of the grease to hold its shape. Higher consistency means the more solid the base and thickener combination will be. If a grease is applied with a consistency too low for the operating circumstances, leakage or excessive churning can result. When consistency is too high, there's a risk of poor lubrication caused by the inability of the stiff grease to slump and flow back between the rollers.

Viscosity is a key characteristic for choosing the right lubricant for a rolling element bearing.

About 70% of the thickeners used in grease are metallic soaps. They include lithium and lithium complex (the two most popular), lithium calcium, calcium, calcium sulfonate complex and aluminum complex. Other thickener types include polyurea, bentonite and silicone.

An example of one of the most widely used grease formulations uses a lithium thickener and ranks 2 on the NLGI stiffness scale. It is made from a mineral oil base, with the viscosity selected according to the bearing size and rotating speed.

"Why can't we just use this formulation wherever grease is required?" Oliver asks. "There is a long list of reasons for an applications engineer to choose a different type of grease." Adjustments to the formulation are needed if the operating temperature is above 100 C or below 50 C, if speed is very high or very low, if heavy loads or shock loads are present or if a number of requirements must be met, including corrosion resistance, low noise or running under vacuum conditions.

Ultimately the life span of a bearing is calculated around fatigue in the metals from which it is made. Assuming the bearing is well- and properly lubricated, the loads and speeds it sees in service are major variables affecting longevity. The other one is contamination, if there is any. Solid contaminants, particularly those above 10 microns in diameter, are murder on metal and can quickly shorten the life of machinery. TLT

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