Application analysis for lubrication of rolling bearings

For the reliable operation of rolling bearings, correct lubrication is a vital and all too often overlooked factor.

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The main purpose of a lubricant is to separate the metal surfaces of the bearing's components with a thin lubricating film to prevent wear. At the same time, the lubricating film reduces friction and therefore power dissipation, resulting in reduced energy consumption of the whole system.

About 40% of all premature bearing failures are caused by lubrication problems. The reasons are varied and start with mistakes during bearing installation – like insufficiently cleaned bearing locations, incorrect grease packing, and damaged seals and covers – as well as incorrect maintenance, such as failure to re-lubricate on time or using to much or not enough lubricant. Some problems can be traced back as far as the design stage of an application, with designers paying too little attention to the bearing arrangement and lubrication system.

The following are some critical points to consider when designing a bearing configuration's lubrication system and selecting a lubricant.

Bearing size and type

The type of bearing used generally affects the lubrication requirements. Tapered roller bearings or spherical roller thrust bearings, for example, exhibit a sliding friction between guide flange and roller end faces in addition to the rolling friction between rolling elements and raceways. Insufficient lubrication in this area quickly leads to permanent damage of the contact surfaces, culminating in a premature bearing failure. Cylindrical roller bearings, which are designed to absorb axial loads, also experience sliding friction between the guide flanges and roller end faces. Sliding friction also occurs between cage and rolling elements and – with ring-guided cages – between cage and guide ring.

Bearing load

The key here is the relationship between the loads occurring during operation and the bearing's load capacity. Bearings are already considered highly loaded at 15% of their dynamic load capacity. At this load level, the use of lubricants with EP (extreme pressure) additives should be considered. Impact loads and vibrations can also affect the choice of lubricant.

Bearing operating temperature

Temperature has a decisive impact on the lubricant's viscosity and therefore also the separating effect of the lubricant film. To ensure reliable bearing operation,

» **Inner ring** of cylindrical roller bearing after operation with excessively mobile oil.

» **Inner ring** of cylindrical roller bearing after operation with sufficiently viscous oil.

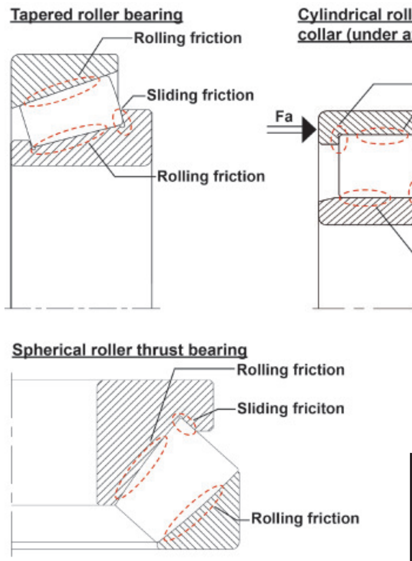
the chosen lubricant must be of a viscosity that is suitable for the operating temperature. Many mineral-based oils age increasingly quickly when continuous operating temperatures exceed +70°C. This can be avoided by using partly or fully synthetic oils.

Low operating temperatures may also have a negative impact. This is especially true for grease-lubricated bearings, since typical greases become considerably stiffer at lower temperatures, increasing the rotation resistance of the bearing. Oil (sump) lubrication, on the other hand, generally results in increased losses due to splashing.

Within reason, temperature peaks should also be taken into account. Considering a lubricant's service life and the resulting re-lubrication and oil change intervals, exaggerated assumptions or excessive cautiousness often results in unnecessarily conservative and therefore economically unviable configurations.

Ambient temperature of bearings

This is especially relevant for arrange-ments with an automatic re-lubrication system. The lubricant usually reaches a higher temperature at the bearing location



» **Friction** at rolling contact and guide flanges.

than it has in the feed lines. At low ambient temperatures the grease can stiffen in the lines to the extent that it can no longer be fed to the bearing in sufficient quantities.

Bearing speed range

Beside temperature, the bearing's running speed also affects the lubricant's separating action which in turn affects the choice of lubricant viscosity. As a general rule, the higher the speed the better the surfaces are separated and the lower the lubricant's viscosity can be. On the other hand, high speeds (at or near the bearing's limit speed) also result in higher losses and therefore higher operating temperatures. This may make a circulating oil lubrication system necessary, which can cool and filter the oil.

At very low speeds a full separation of the surfaces cannot always be ensured. Brief running at low speed, however, for example at start-up, is not normally a problem. A lubricant with appropriate wear protection additives should be considered in these cases.

Possible bearing contamination

Contamination can have various sources. Dirt, etc. can enter through seals and vents while wear particles from surrounding machine components as well as production residue my be present inside an application. The lubricant itself can also contain contaminants if not stored correctly. These contaminants then enter the system when re-lubricating bearings or during an oil change. Beside solid particles, contaminants also include moisture and chemicals.

In addition to technical factors, the costs of both lubricant and complete lubrication system must be considered. To achieve the ideal balance between technical configuration and cost, the system requirements must be drawn up with care. A neglect of individual aspects is often the cause of problems later on. Conversely, if excessively high demands are made on the lubricant or unrealistic assumptions about the operating conditions, costs for the lubricant or the lubrication system can rise quickly and unnecessarily. As there are many different lubricants to choose from, consult the lubricant manufacturer when selecting a product.

Using a few application examples, here are some of the effects of lubrication on the function of bearings.

Example 1: Cylindrical roller bearing in a PTO transmission

As part of a theoretical consideration of the bearings in a power take-off (PTO) gearbox, the lubrication was investigated more closely. It was found that, under the given operating conditions, the lubricant's viscosity was much too low to form a sufficiently effective lubricant film. Increased wear and a reduced service life would have been the logical consequence. The use of a more viscous, i.e. thicker lubricating oil was recommended.

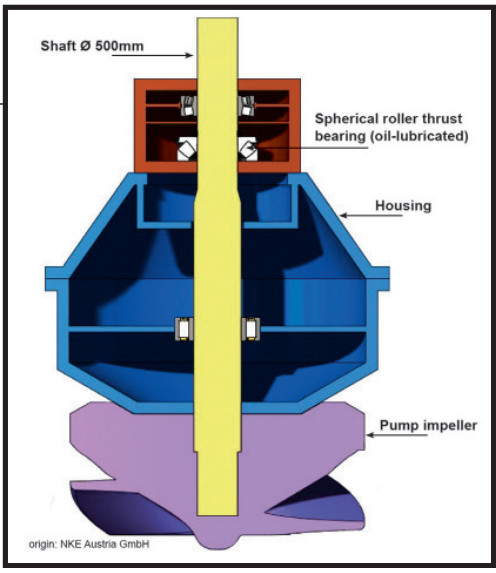
As a precaution, a practical test was performed, in which two identical gearboxes were filled with the lubricating oils to be compared and run for a period of 500 hours. In the subsequent survey, discolorations and initial signs of wear were clearly visible on the functional surfaces of the bearing run with the thinner oil. The bearings operated with the thicker oil did not show any signs of wear.

The customer's fear that the thicker oil would result in higher power dissipation proved unfounded. On the contrary: the gearbox with the more viscous oil exhibited lower losses and therefore also a reduced operating temperature. This can be attributed to the better separation of the metallic surfaces in operation, which more than compensates the slightly higher fluid friction.

Example 2: Spherical roller thrust bearings in a cooling water pump for a thermal power plant

During test operation of a large cooling water pump, (concrete volute pump, i.e. a centrifugal pump with vertical shaft in a cast concrete housing) the axial bearing at the drive end repeatedly exceeded its permissible operating temperature, resulting in an automatic shutdown. On closer inspection, the use of an unsuitable lubricant for this application was identified as the culprit. The oil in question was a pure hydraulic oil, which did not in any way meet the bearing's requirements in terms of either composition, i.e. AW- / EP-additives, or viscosity.

The high measured operating temperature was the direct result of the metallic contact and resulting friction especially between the side faces of the rolling elements and the guide lips of the shaft locating washers. This resulted



» Concrete volute pump with vertical shaft.

in irreversible damage to the bearings' functional areas within just a short time, in effect preventing reliable long-term operation. The bearings had to be replaced at considerable expense on site.

By changing to a suitably viscous oil selected for the application parameters and the use with spherical roller thrust bearings, a reliable separation of the contact surfaces and a low operating temperature were achieved. The plant has now been in fault-free operation since 2009.

Example 3: Deep groove ball bearing in a screw pump

The screw pump in this example delivers fuel – both heavy and light oil – to marine diesel engines. To allow the oil to be more readily pumped and injected into the combustion chamber, it is first heated up. Consequently, the screw bearings are also exposed to the high temperature of the fuel oil.

To realize the simple bearing concept required by the customer, i.e. a deep groove ball bearing with integrated seals, engineers conducted a theoretical analysis of the setup. At the bearing temperature of +150°C initially estimated by the customer, a satisfactory solution was out of the question: The lubricant's calculated service life based on this operating temperature, and the associated life of the bearing, fell clearly short of the required values.

Following further consultations with the client, a temperature measurement was carried out on a test setup to determine the actual operating conditions. The result was a maximum bearing temperature of "only" +130°C. With the selection of a lubricating grease for this temperature range, in cooperation with a lubricant manufacturer and by maximizing the amount of grease in the bearing, the specified service life could then be achieved.

As can be seen from the above examples, the operational reliability of bearings can be improved by correctly assessing and adjusting the lubrication. As a general rule, the sooner the issue of lubrication is addressed, the easier and more cost effectively potential problems can be avoided.

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