Effect of Water and Temperature on Bearings

Temperature's Effects on Mounted Bearings

Most rolling element bearings can operate successfully at temperatures well above the pain threshold of a human hand. The stabilized operating temperature of a bearing is the result of many factors. The key influences on operational temperature are bearing style, lubrication type, operational factors, environmental conditions and level of maintenance The particular bearing style (ball, roller, sleeve, etc.), the shaft mounting style (slip fit, adapter mounted, press fit, etc.) and auxiliary items (housings, seals, shields, flingers, etc.) all contribute to a final operating temperature. For a given set of application conditions, a particular bearing type will generate friction given off as heat. A typical bearing temperature rise range would be 40° to 80°F (4° to 27°C) for most industrial applications. However, a bearing temperature rise over ambient of up to a 120°F (49°C) can be observed at extreme conditions.

It should be noted when bearings operate at higher than normal temperatures, service life may suffer due to a deterioration of the lubricant oil film thickness and quality. The initial bearing selection should either be chosen with adequate design life hours to compensate for the anticipated reduction in service life or an appropriate lubricant for high temperature operation should be selected.

Bearings may be exposed to abnormally high ambient temperatures or elevated temperatures in equipment such as furnaces, fans, ovens, blowers, steel mill/foundry casters, roll out tables, dryers, electric motors and generators, to name a few. In many of these cases, bearings are expected to operate above the limits for standard bearing products.

If at all possible, locating bearings out of the immediate heat zones or providing provisions to reduce bearing heat are preferred means to achieve optimum bearing service life performance. This can be accomplished by insulation procedures to reduce radiant heat. Also, shaft heat flingers or cooling wheels coupled with heat resistant shaft materials can reduce bearing temperatures. The use of water- or air-cooled bearing units is another method to reduce bearing temperatures to a more manageable range. Though these steps incur higher installation costs, long term benefits may be gained by reducing lubrication and maintenance problems often encountered with high temperature bearing applications.

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When there is no way to avoid heat exposure, bearings can be specially modified to accommodate high temperature applications. Bearings having optional components materials, special internal radial clearances, high temperature lubricants and special heat treatments (if necessary) can operate successfully at very high temperatures, as shown.

Bearing Type - Special Modifications	Allowable Max. Temperature (°F)
Normal, Medium & Heavy-Duty Bearings	Up to +550°
Spherical Roller Bearing Units	Up to +450°
Split Block Roller Bearing Units	Up to +450°
Cylindrical Roller Bearings	Up to +300°

The above maximum operating temperatures are limited by either the standard bearing unit features, component materials or lubrication provided

Bearings can provide years of service while operating at temperatures well above ambient and at levels well above what is commonly called "too hot." As with any equipment component, proper bearing selection, correct lubrication and adequate maintenance procedures are vital to satisfactory service life

MOISTURE - The Second Most Destructive Lubricant Contaminate, and its Effects on Bearing Life

Moisture is generally referred to as a chemical contaminant when suspended in lubricating oils. Its destructive effects in bearing applications can reach or exceed that of particle contamination, depending on various conditions. Like particles, vigilant control must be exercised over entry of water to minimize its accumulation in the lubricants and its damage to bearing surfaces.

This paper will discuss the influence of moisture on the chemical stability of a lubricant's additives and base stock. The effects of moisture on machine surfaces, particularly as relates to wear and corrosion, will also be discussed. Finally, a three-step, proactive maintenance strategy will be proposed to minimize the effects of moisture on lubricant and bearing life.

States of Co-existence in the Lubricant

Once water enters the casing of a machine where bearings are used, such as an engine, turbine, or gear box, it may move through several chemical and physical states. These changes are complex, but important to understanding how to control and analyze its movements. To begin with, water will enter an oil in generally one of the five following ways:

(1) Absorption. Oil is hygroscopic to a certain extent, meaning it can absorb moisture directly from the air. The amount of moisture that can be absorbed is influenced by the relative humidity of the air and the saturation point of water solubility in the oil. Depending on temperature and pressure, this solubility limit will vary from about 100 ppm for low additive oil to several thousand ppm for high additive and certain synthetic oils. For any given water-in-oil saturation point and relative humidity of ambient air, an equilibrium will eventually be attained where the moisture moving from the air to the oil, and also from the oil to the air, is equal. Absorbed water is always dissolved in the oil at first, but may later, due to temperature/pressure changes, be condensed out to a free or emulsified state.

(2) Condensation. Humid air entering oil compartments will often cause moisture condensation on the walls and ceilings above the oil level. Frequent temperature change cycles may greatly increase the rate of condensation. Eventually the condensation will coalesce and run down the casing walls to the bottom forming a layer of free water or puddle.

(3) Heat Exchangers. Corroded or leaky heat exchangers are common sources of water contamination in lubricating fluids. In extreme cases, a rupture of the heat exchanger can cause massive amounts of water to enter the machine compartment.

(4) Combustion/Oxidation/Neutralization. Fuel combustion in engines forms water in the exhaust gases as a by-product. This is combined with the water from the induction air. Problems associated with worn rings/liners and improper scavenging can cause water to enter the lube oil. Low jacket-water temperature and intermittent operation may prevent the water from easily vaporizing out of the oil compartment. Water can also be created in oil as the chemical reaction product resulting from certain types of corrosion and oxidation processes. In engine oils, water is also formed when alkalinity improvers neutralize acids formed during combustion.

(5) Free Water Entry. During oil changes or the addition of makeup fluid, water can be introduced to oil compartment. Condensation of water in storage containers is the most common origin of this water.

Water, once in an oil, is in constant search of a stable existence. Unlike the oil, the water molecule is polar, which greatly limits its ability to dissolve. Many additives have polar extremities which can markedly increase water's limit of solubility. In the absence of dissolved polar compounds to which water can attach, water may cling to hydrophilic metal surfaces or even form a thin film around polar solid contaminants such as silica particles. Or, if a dry air boundary exists, water molecules may simply choose to migrate out of the oil to the far more absorbent air interface. This migration can be further facilitated where air and oil mix (such conditions where high air/oil surface area are created) such as in splash lubricated and oil mist systems or any fluid system where a stable foam may exist.

If increasing amounts of water molecules are unable to find polar compounds to attach themselves, the oil is said to be saturated. Any additional amounts of water will result in a supersaturated condition causing free water to be suspended or settle in puddles at the bottom of the sump. This super saturation can also occur as a result of lower oil temperature. When free water is suspended, a colloidal suspension or emulsion is said to exist. This causes a visible cloud or haze in the oil. By lowering interfacial tension (below 25 dynes/cm), certain dispersant additives (engine oils) and emulsifying agents can permit water in oil emulsions in excess of 10% water. Typical low-additive industrial lubricants will hold no more than 0.5% water in an emulsified state. The higher shear rates associated with high speed systems can create micro emulsion of water in oil that inhibits coalescence and settling of the water.

The Effects of Water on Additives and Base Stock Lubricants

With few exceptions, the chemical and physical stability of lubricants are threatened by even the slightest amount of suspended water. Water can promote a host of chemical reactions (hydrolysis) with compounds and atomic species including oil additives, base stock and suspended contaminants. In combination with oxygen, heat, and metal catalysts, water is known to promote the oxidation and the formation of free radicals and peroxide compounds. Oxidation inhibitors are sacrificed by both neutralizing peroxides and breaking oxidation chain reactions to form stable compounds. Other oxidation inhibitors are known to form hydrogen sulfide and sulfonic acids when reacting with water. Experiments have shown the protection provided by zinc dialkyl dithio phosphate (ZDDP), a common antiwear additive and antioxidant, to be destroyed by as little as one drop of water in a gallon of oil, with oil temperature above 180 degrees F (82 degrees C).

Water is also known to attack rust inhibitors, viscosity improvers, and the oil's base stock. The effects are undesirable by-products such as varnish, sludge, organic and inorganic acids, surface deposits and lubricant thickening (polymerization). Large amounts of emulsified water can lower viscosity, thereby reducing a lubricant's load carrying ability. When water is combined with metal catalysts such as iron or copper, accelerated stressing of the oil can occur. This results in base stock oxidation and the forming of free radicals (which continue the oxidation process), hydro peroxides, and acids.

Summary

Moisture is known to enter lubricated bearing systems in several different ways resulting in dissolved, suspended or free water. Both dissolved and suspended water can promote rapid oxidation of the lubricant's additives and base stock resulting in diminished lubricant performance. Rolling element bearings may experience reduced fatigue life due to hydrogen embrittlement caused by water penetrated bearing surfaces. Many other moisture-induced wear and corrosion processes are common in both rolling element and journal bearings. The best defense against moisture contamination is a three-step, proactive maintenance strategy called Target-Exclusion-Detection (TED). Only when lower moisture levels are consistently stabilized can the life extension of lubricants and bearings be effectively achieved.