Run Times
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In this month's issue we address lubricating oil contamination and deterioration. Most modern day rolling element bearing assemblies are designed with an L-10 life in excess of 40,000 hours. In practice, many bearings never realize their design life. Lubricant deterioration due to oxidation and contamination caused by moisture and particulates are accountable for about 20% of all rolling element bearing failures.

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Oxidation

Oxygen will chemically combine with lubrication oil and its additives to create a variety of oxygenated byproducts. Oxidation raises oil acidity, viscosity, and surface deposits, all of which can shorten bearing life. An open container of oil exposed to atmosphere will absorb about 10% Oxygen.

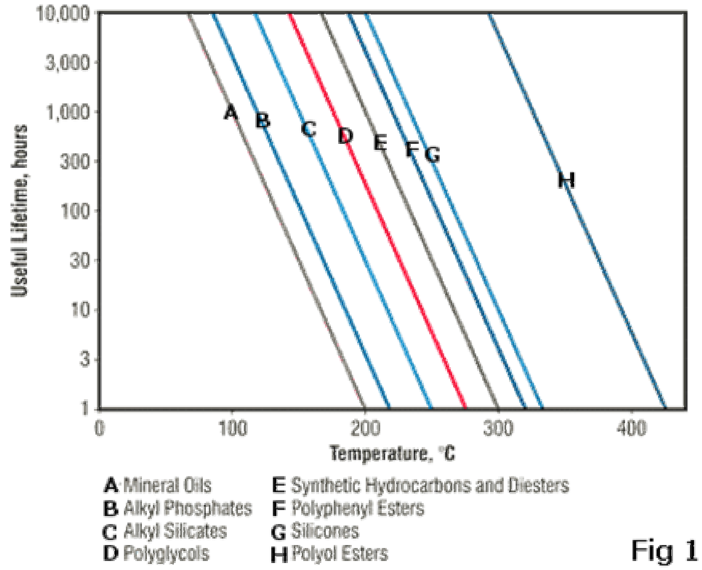

Fig 1

Oil additives are usually the first to be impacted by oxidation followed by the base stock. The rate at which oxidation occurs in lubricating oils is primarily dependent on the oil, temperature, moisture content, and lubrication environment.

Operating temperature has a tremendous impact on oil oxidation. Figure 1 illustrates the effect of temperature on a variety of oils. For every 10°C (18°F) rise the rate of oxidation doubles. Oil operating at 50°C will last 30 times longer that oil operating at 100°C. The presence of oxidation inhibitors will slow the process. However, these will eventually be consumed and the oxidation will continue unabated.

Moisture

Moisture becomes entrained in the oil either directly through contact with free water or through absorbsion. Water molecules are polar, that is to say they have positive and negatively charged particles that are readily available for bonding with other molecules. Many of the additives and particulates in lubrication oil are polar as well. Water molecules are attracted, and become attached to these available polar molecules. The amount of moisture that oil can absorb is dependent on the amount of additives, as well as temperature and pressure. Once moisture has attached itself to all of the available polar molecules, the oil can be said to be saturated. Beyond this point water will start to collect as condensation of free water in the bottom of the sump.

Free water may enter the sump from leaking heat exchangers, steam from adjacent quench connections, wash downs, and condensation within the bearing housing during temperature cycles

Moisture in any form accelerates oxidation. It reacts with and promotes the breakdown of oil additives, and also forms acids. It promotes the localized fatigue of bearing surfaces, and the oxidation of unprotected metal surfaces within the bearing frame, both of which add to the particulate load within the oil. Figure two shows the life extension that can be achieved by reducing moisture content. For example, oil with 500 ppm moisture content would experience a 3x life increase if the moisture content were reduced to 65ppm.

	Life Extension Factor									
	ppm	2	3	4	5	6	7	8	9	10
Current Moisture Level	50,000	12,500	6,500	4,500	3,125	2,500	2,000	1,500	1,000	782
	25,000	6,250	3,250	2,250	1,563	1,250	1,000	750	500	391
	10,000	2,500	1,300	900	625	500	400	300	200	156
	5,000	1,250	650	450	313	250	200	150	100	78
	2,500	625	325	225	156	125	100	75	50	39
	1,000	250	130	90	63	50	40	30	20	16
	500	125	65	45	31	25	20	15	10	8
	250	63	33	23	16	13	10	8	5	4
	100	25	13	9	6	5	4	3	2	2

Table 1. Moisture Life Extension Method   Fig 2

Particulates

Particulates not only damage the bearings directly, but indirectly as well. Many particulate molecules are also polar and therefore increase the moisture load carrying capability of the oil. In addition Iron and Copper act as catalysts and react with the oil to form acids.

The amount of direct damage that particulates have on the actual bearing surfaces is dependent on the particulate concentration, hardness, size and shape. On the Mohs's hardness scale,[1] tool steel is 7.0; unfortunately, dirt, dust, and grinding abrasives, to

[1] A scale of 1-10 used in the measure of mineral hardness with Babbitt being 1.0 and Diamond being 10.

name a few common contaminants, all have Alumina and Silica with a hardness of 7-9 Mohs. These particles have sharp irregular shapes making them especially abrasive and are often small enough to enter the clearance areas of the bearings. If all is equal in terms of the types of solid contaminants present, then bearing life is certainly dependent on the quantity of solids. This makes particulate counts an acceptable indicator when conducting oil analysis.

Improving Lubrication Quality

Establish Objectives

Set some targets for your lubrication monitoring program. What these targets should be is very dependent on the application, oil selected, and the environment. Targets can later be adjusted based on measurements and operational results. A reasonable start would be 200 ppm of moisture as a maximum and an oil cleanliness standard based on ISO 4406:99 cleanliness codes. (Fig 3)

ISO Oil Grade Classification	Cleanliness Code ($R_4/R_6/R_{14}$)
32	16/14/11
46	16/14/11
68	17/14/12
100	18/15/13
150	18/15/13
220	19/16/14
320	19/16/14
460	19/16/14
680	20/18/14

Fig 3

Measure

The old saying "If you want to improve it, measure it" applies. Institute an ongoing lubrication oil monitoring program. Monitoring and testing equipment and services are readily available, and are a cost effective alternative to increased repair cycles.

Protect

Oil can't become contaminated if the contaminants can't get in.

- Store oil in sealed containers
- Keep oil inventories low so as to keep turnover frequent and oil fresh
- Store oil drums in drum racks where they won't collect water
- Make sure the inside of bearing frames are coated and free of rust
- Work on pumps in a clean environment
- Use labyrinth, or magnetic oil seals, and non vented oilers
- Purchase quality oils
- Lower bearing operating temperatures where possible

Note that many of the contaminant and deterioration factors are interdependent. Increased particulates will increase moisture retention which, in turn, increases oxidation. Increased oxidation, or increased moisture, can increase particulate loading…etc. Unchecked, these factors will compound to work against the life of the equipment. Conversely, reducing any of these factors can compound to improve equipment life. Lubrication related problems can be a silent machinery killer. A high moisture or oxygen content is not always visible. A good proactive lubrication oil program will extend the life of equipment throughout the plant.

Acknowledgements:

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