Lubrication: The Life Blood of the Machine

EMERSON™

Tribology is an Integral Part of Reliability-Based Maintenance

Oil analysis is a non-intrusive means of determining whether the oil system is clean and dry, if the oil is fit for use, and if wear is occurring inside the machine A machine's operating life is most often determined by the oil that lubricates its load-bearing surfaces. Good lubrication normally provides long life, even under harsh operating conditions, and poor lubrication results in short life, even under mild operating conditions. Industrial machines are generally supposed to have 40,000 hours (about 5 years) mean time between failures (MTBF). This only happens if you have good lubrication. If you have poor lubrication or no lubrication at all, you get far shorter operating life.

There are five factors in maintaining good lubrication:

- Clean oil
- Dry oil
- Oil with the right properties
- Contamination control
- Wear debris monitoring

Particle counting is used to monitor the cleanliness level of the machinery. The cleaner the system, the longer the equipment lasts.

Wear debris analysis is used to identify the root cause of abnormal conditions. This analysis of large particles provides the essential difference between conventional oil analysis and industrial oil analysis.

Check for **water-in oil**:

- Crackle test detects the presence of water
- Karl Fisher Test method measures the level of moisture

Viscosity is one of the most important properties of an oil. Without the correct viscosity a machine will not have the correct lubrication, resulting in severe damage. Viscosity is measured at 40°C and 100°C. Spectrometric analysis is used to measure wear metals (particle size typically less than 5 microns), contaminants such as silica (dust), and additive levels (adding wrong lubricant, additive depletion).

Chemical analysis requires one of the following tests:

- Total Acid Number (TAN) measures the extent to which a lubricant has been oxidized by monitoring the acid content.
- Total Base Number (TBN) measures the amount of neutralizing agents still available to counteract the acid build-up.
- Dielectric permittivity measures the amount of acids and other polar constituents of the lubricant. Oil Storage & Handling

Oil Storage & Handling

- "Fingerprint" your lubricants to ensure correct labeling, using:
    - Dielectric
    - Viscosity
- Clean up
- Label containers and equipment
- Accurately label sample bottles
- Store lubricants in clean, dry location and use desiccating breathers
- Transfer lubricants using dedicated, tagged totes

Cleaning up your oil storage and using clean and correctly labeled storage containers is the first step in gaining control of your lubrication program.

Care should be used when handling lubricants. Incoming and used oils should be checked for contamination and to ensure that the correct oil is being used. Many problems may occur with wrong, mixed, and contaminated oils throughout the plant.

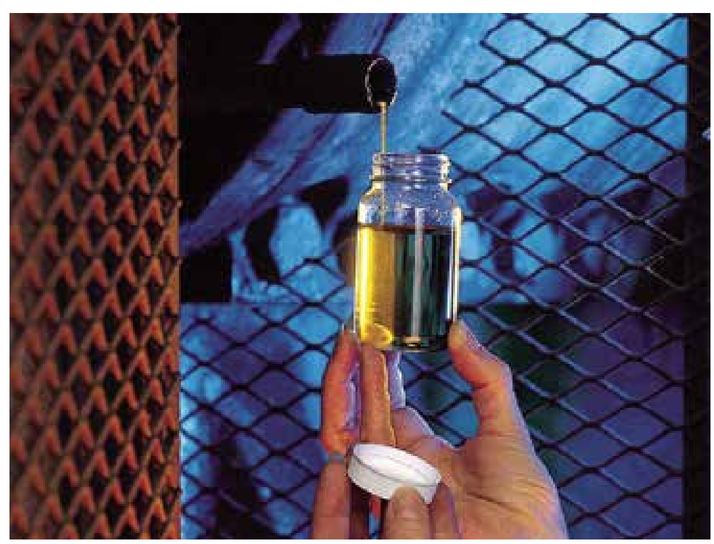
Efficient, well-labeled oil storage

Unorganized storage creates confusion

Oil Sampling & Testing

The number of oil samples collected should be in proportion to the number of oil-lubricated systems in the plant. A steel mill or mining operation should collect 500 to 2000 samples each month. An average for most industrial mills or plants is between 20 and 200 samples per month. For example, in a plant with 3000 vibration points on lubricated pumps, motors, compressors, turbines, gearboxes, air handlers and hydraulic systems, there are probably 100 or more oil points which should be sampled monthly.

Collect oil samples from actively flowing circulating oil systems, and sample from the return line from the machine if possible.



Contamination Control

Contamination can best be controlled by learning what the contaminant is and identifying where it is coming from. Contamination may have many sources, including moisture acquired while sampling oil. Dirty or hazardous environments such as coal handling or chemical or oil refineries have their own problems, as do cement plants and wet environments, or situations with varying temperatures. Proper storage and handling of lubricants is a necessary first step, but this is often not enough. Exclusion technologies such as ensuring proper sealing of lubrication reservoirs on machinery is often the right solution. Filtering systems such as exclusion breather systems can greatly reduce contamination of particulates as well as moisture. Regardless of what solution is successful for your application, regular monitoring is necessary to maintain the integrity of your lubrication program.

Wear Particle Identification

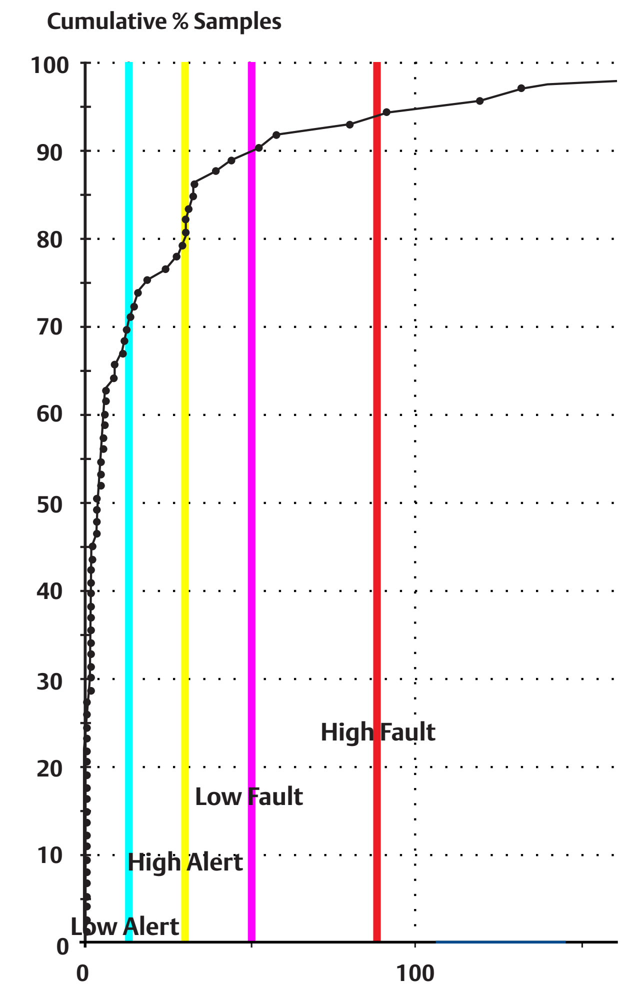
No industrial oil analysis is complete without a comprehensive wear debris analysis. Wear debris analysis (WDA) is a non-intrusive way to see inside complex machinery without taking it apart. Accurate identification of wear debris fragments can tell you which machine elements are damaged, and the nature of the problem which generated the debris. Most (80%) of abnormal machine wear comes from one of four mechanisms: abrasion, fatigue, adhesion, or corrosion. WDA tells you both the mechanisms and the severity. Armed with this knowledge, you can go after the corresponding root causes such as dust contamination, vibration faults, lube starvation, or water contamination.

1. Fatigue wear particles can show damage in a hidden gear tooth, excess force in gearing, or delamination in a bearing race.
2. Abnormal boundary wear fragments can demonstrate heat during particle creation, or surface-to-surface contact under load (striations). Sometimes this is called adhesive wear.
3. Abrasive wear particles are formed when a body in motion penetrates a surface and gouges out part of that surface.
4. Corrosion and fretting wear result in very small black platelets, rusted particles, and very small (less than 5 microns) particles caused by additive depletion or corrosive contaminants.
5. Contaminants shown in wear debris analysis may include salt crystals, sand, or fibers.

Histogram Plotting

For each group of machines, create an Alarm Limit (AL) Set. AL and oil references are essential elements of analysis systems, used to verify that results gathered from sample testing are within acceptable ranges. Test a clean unused oil sample and use this as a reference. Care must be used to set alarms, as there are often conflicting OEM recommendations and varying operational environments.

Alarm Limits allow abnormal data to draw focus and aid in the early identification of machine failure. Assign specific Alarm Limits to groups of like machines to facilitate statistical analysis. Once ample historical data is available, the use of Histogram Plots can simplify optimizing Alarm Limits.

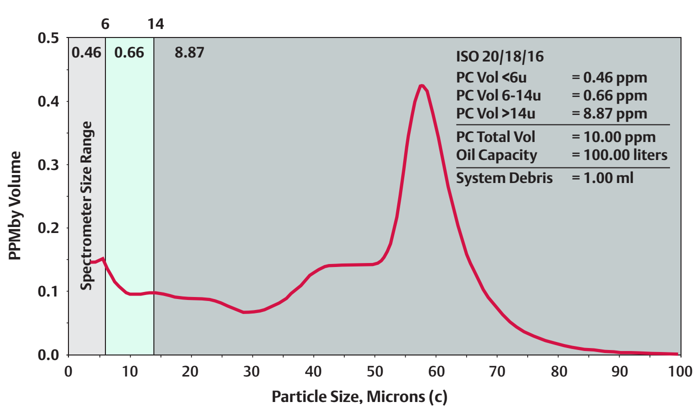


Particle Counting

For wear analysis, if you know how much metal is in the lube system, you know how much material has been removed from the machine.

For contamination analysis, if you know how much particulate is in the oil, you know how much filtration will be needed to remove it.

The ISO cleanliness code is a convenient way to report the number of particles per milliliter in these size ranges: 4 microns, 6 microns, >14 microns.



Trivector Plotting, Onsite Monitoring and Lab Services

Three Essential Elements

Determine Oil and Machinery Condition:

1. Wear

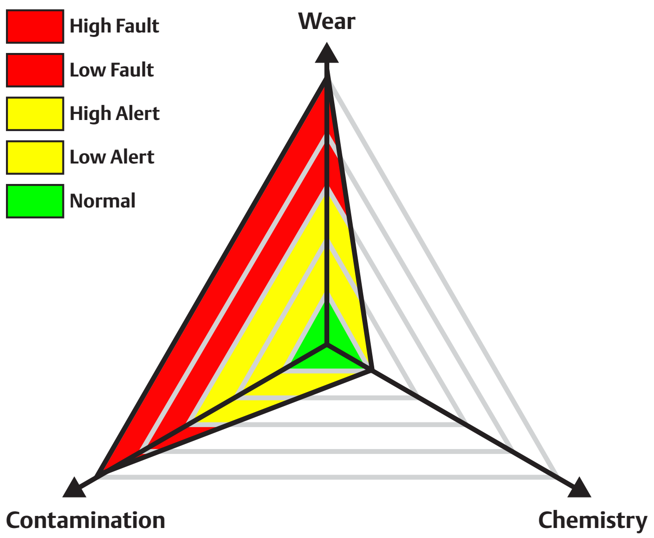
2. Chemistry

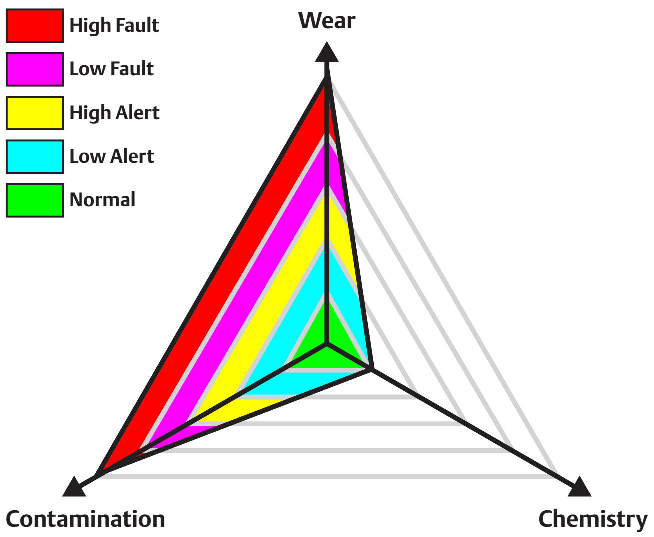
3. Contamination

The color coding of alarm states and trend plots make this process simple. Three or five colors may be used.

Oil analysis provides particle count and water contamination data that give a clear indication of the cleanliness of the system which is directly related to equipment life.

Ferrous wear indices and wear debris analysis combined with vibration analysis give a clearer indication of the source of a problem.





Onsite Oil Monitoring

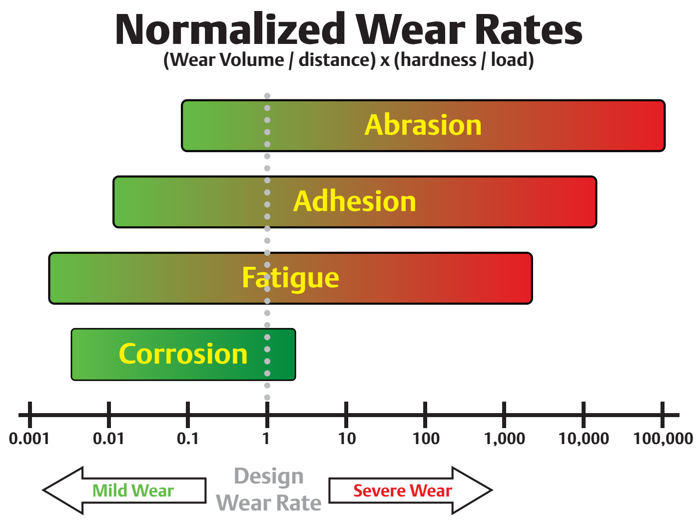
A good quality onsite lab can give you immediate reports on the major issues of your lubrication:

- Oil deterioration and suitability measured by Dielectric and Viscosity
- Water and ferrous content
- Particulate contamination and particle size distribution measured by laser particle counter
- Root cause and severity of problem determined by wear debris analysis
- Immediate tests are possible when problems are found

Oil Analysis Lab Services

An industrial oil analysis laboratory can provide a complete, detailed study of your oil samples:

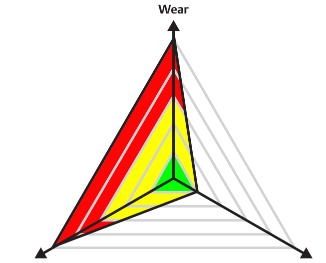
- Water determination will reveal a common serious problem
- Particle count is the physical counting of particles in a sample at various sizes
- Spectronomic analysis measures minute metal, silica, and additive contaminants
- Total Acid Numbers (TAN) measures oxidization
- Viscosity is measured at different temperatures
- Fourier Transform Infrared Absorption spectroscopy measures nitration levels, sulfate levels, soot content, fuel dilution, oxidation and Oil and Lubrication Issues



Abrasion

Abrasive wear particles are most commonly the result of dust or dirt in the oil. The dirt particles become wedged between two moving parts, embed in the softer surface, and cut into the harder one. The wear debris from this process appear to be miniature shavings from a machining operation. Abrasive wear particles can be several hundred microns long. Hard metals tend to form smaller abrasive particles that may have a needle-like appearance.

The primary corrective action for abrasion is to filter the oil to remove contaminants. It is also important to minimize the future ingress of contaminants, especially dust.



Ribbon from abrasive wear

Couging Fragment

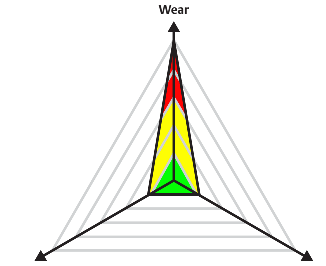
Ribbon caused by abrasive wear

Fatigue

Fatigue wear is the result of repeated cyclic loading of surfaces with compression and shear or compression and tension. This is most common in industrial bearings and gears.

The repeated loading of the same point on a gear or bearing causes microcracks to form and become interconnected. When the cracks intersect surfaces, spall occurs, and flakes or chunks are released into the oil. These particles are commonly 10 to 30 microns at first and later grow to be 100 microns or more. Fatigue is often from one of the following root causes: improper assembly, alignment, balance, or other condition that concentrates loading in a non-uniform distribution.

The corrective action for premature fatigue is typically to use another technology such as vibration to find possible causes and minimize those. Fatigue will eventually require component replacement.



Fatigue pitting on bearing surface

Gear tooth chunks

Ribbon from abrasive wear

Needle from gear tooth fatigue

Corrosion & Lubrication Degradation

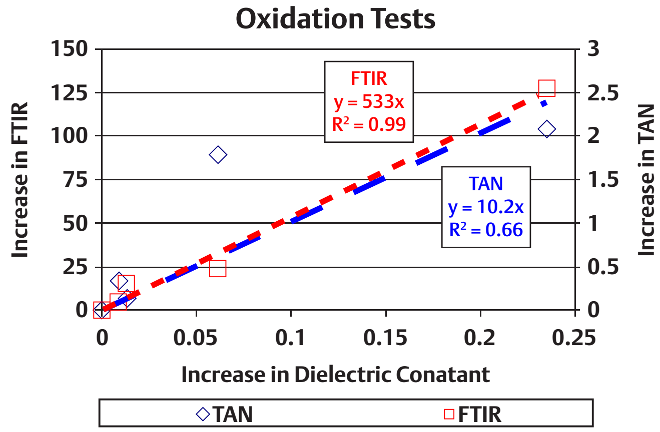
Corrosion problems are caused by water or other corrosive process media in oil, such as natural gas compounds or sulfur.

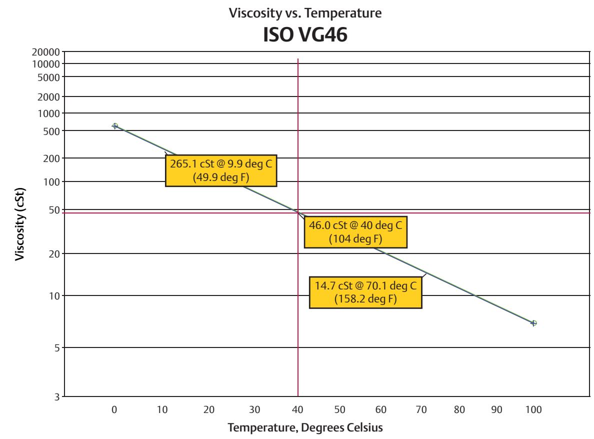
Corrosion is especially a problem in refineries and crude oil processing facilities. Corrosive wear in industrial machinery is normally caused by contamination of the oil with water or other corrosive fluid.

Corrosive wear in engines can also be caused by the degraded oil. Oxidation is a common way that oil gets degraded. Oxidation is caused when hydrocarbon oil molecules chemically react with oxygen from combustion gases, atmosphere, or moisture.

Long-term high-temperatures cause rapid oxidation. Measure change in dielectric constant, Total Acid Number (TAN) or Fourier Transform Infrared (FT-IR Oxidation) to give an indication of when to change oil.

Also look at the color of the oil. If it is degraded, then it will be very dark in color (brown to black). Keep in mind that it may be dark and still perfectly good, but if it is bad due to oxidation or other chemical deterioration it should also be very dark. Dielectric increase of 0.1 usually means it is time to change the oil.

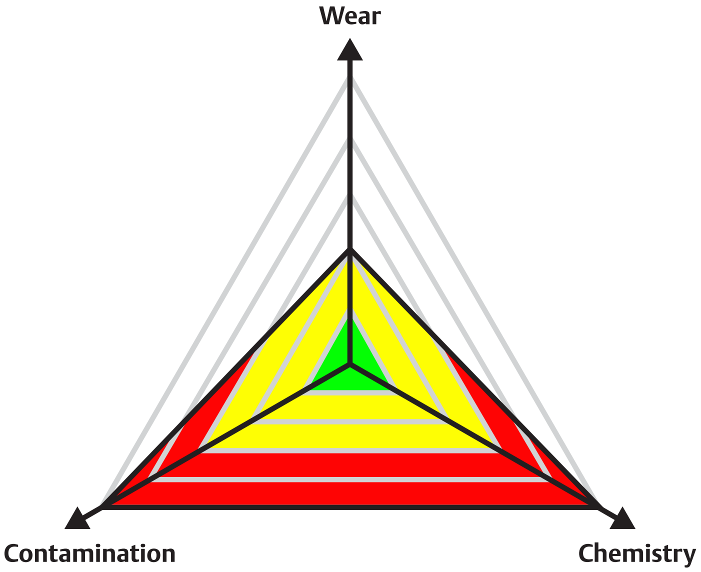




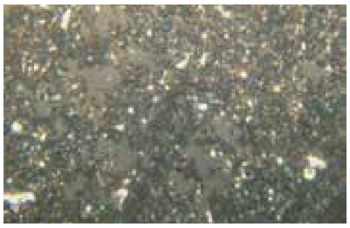
Varnish formation due to oil degradation

Changing oil formulation eliminated oil varnish problem and premature overhauls

Lubrication degradatio particles



Rust from water contamination



Corrosion wear particles (1000x)

Boundary Lubrication Issues

ADHESION

Adhesion is the result of two parts that drag across one another without adequate lubricant-film separation. This is also called boundary wear or boundary lubrication. The particles can be scuffed with striations from the dragging. The particles may show signs of melting due to the localized overheating. Spherical particles are common when complete melting occurs.

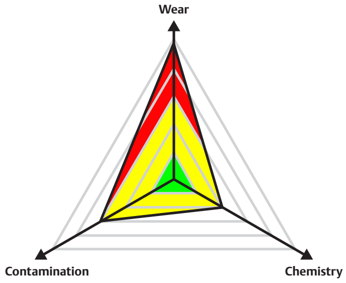
Adhesion can be either normal or abnormal. Normal adhesive wear is a polishing action that generates particles, most of which are 10 microns or less. Abnormal adhesion generates particles 10 microns or greater with the characteristics described above. Abnormal adhesion is caused when the lubricant does not support component loads. Corrective actions include investigating for absence of lubricant, wrong lubricant, dilution of lubricant, excessive loads, and low speeds.

MICRODELAMINATION

Microdelamination is surface damage caused by steady state sliding and metal-to-metal contact at the microscopic asperity level. Damage occurs due to the plastic deformation at, or just below, the surface. The stress creates voids in the subsurface Beilby layer initiating cracks. Cyclic motion causes the cracks to propagate resulting in particles that flake off.

ASPERITY DEFORMATION

Asperity deformation is caused by microscopic asperity contact that results in the asperities on the softer material, plastically deforming, or smearing in the direction of movement. Repeated contact eventually leads to removal of the asperities at the weakest point.



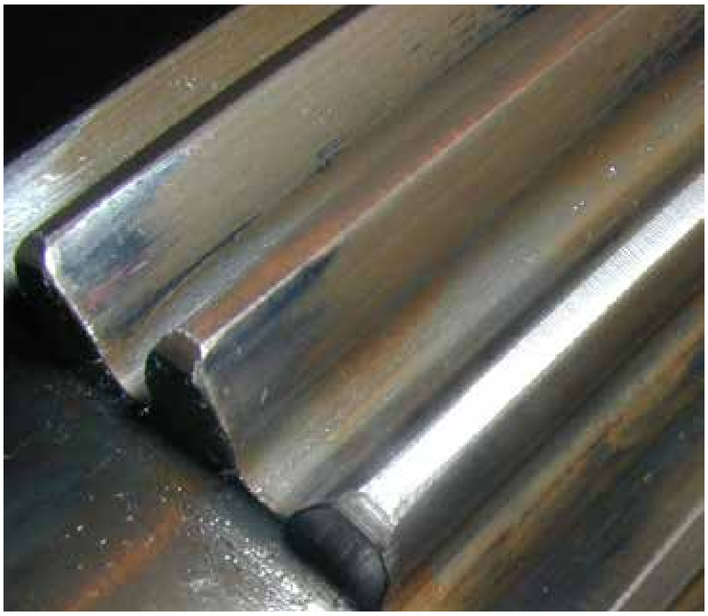
Partially melted particle from abnormal BLW

Spheres & black oxide particles caused by adhersion

Tempered particle from abnormal boundary lubewear

Particle with striation made from severe sliding

Oxodized needles from gear tooth fatigue & abnormal boundary lubewear



Misalignment leading to boundary lubrication wear on outside edges of gear teeth

Monitoring Greasing Using Ultrasonic Technology

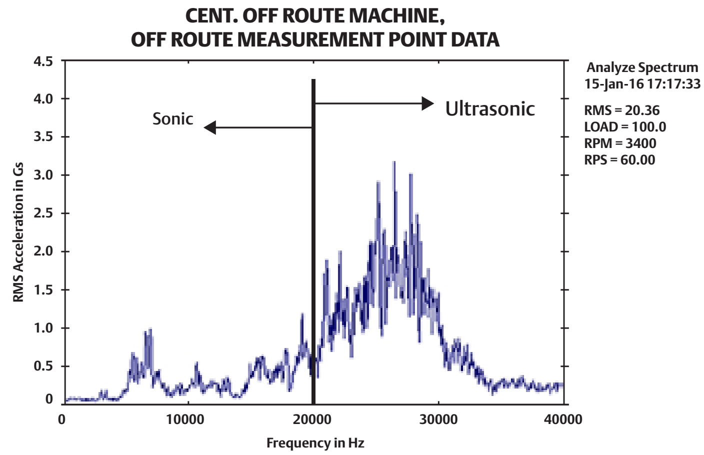
Ultrasonic testing can help determine if low, absent, or excessive lubricant is the primary cause of the problem. It can also help set the best greasing intervals.

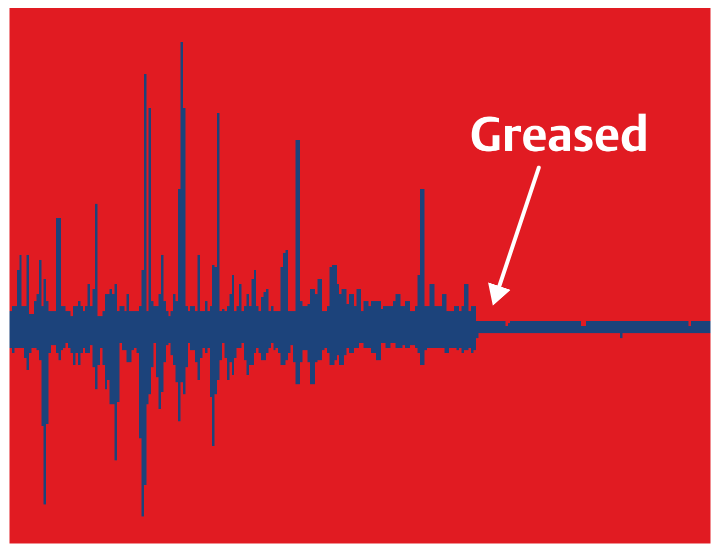
Oil Whirl/Oil Whip

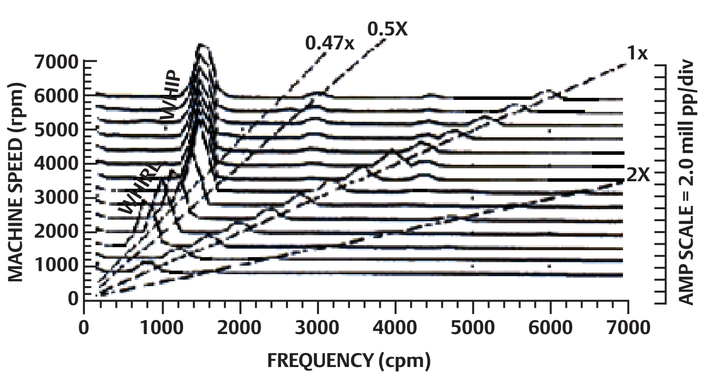
Oil and vibration analysis are complementary and synergistic. Together they provide a more complete and accurate view of equipment health. Vibration analysis can detect issues with lubrication not seen in laboratory analysis.

Oil whirl is a condition of lubrication instability in sleeve-type bearings that induces cyclical rotation (turbulence) of the oil at or near the “oil wedge” which is created by the rotation of the shaft in the bearing.

Oil whip occurs when the rotational frequency of the lubricant wedge (oil whirl) approaches or coincides with the critical frequency of the shaft itself causing a force that pushes the shaft around within the bearing.

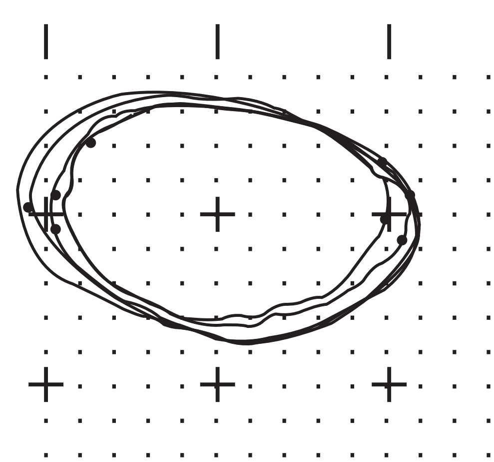


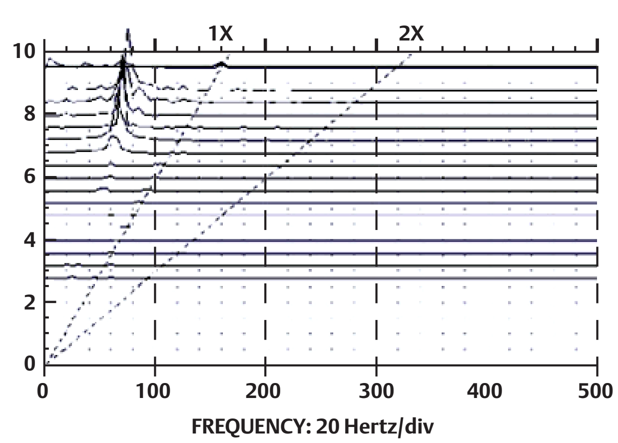




Cascade Plot of Whirl and Whip

Orbit plot illustrating a fluid-induced vibration



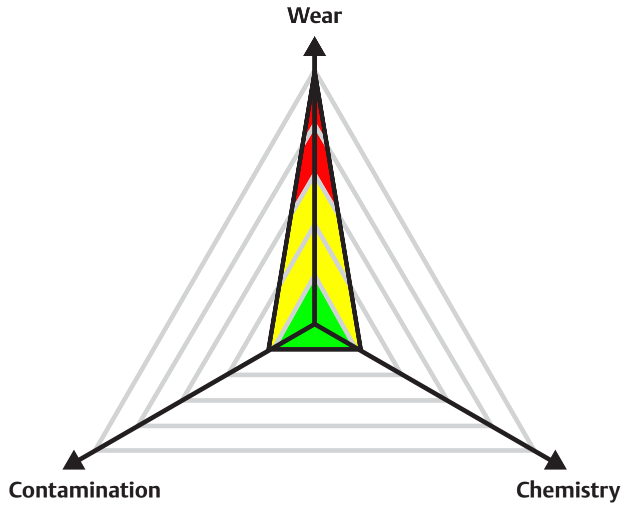


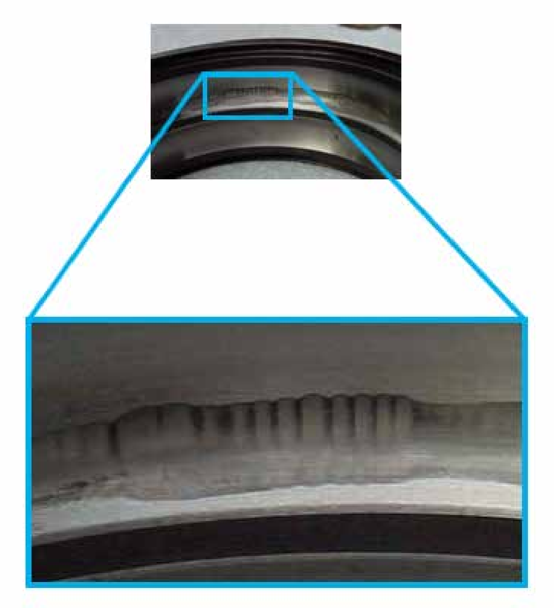
Cascade Plot of Fluid Induced Vibration

Fluting

Electric discharge from an electrically isolated machine can cause pitting in rolling elements as charges arc through the lubricant film to ground the rotating shaft. This is sometimes seen in motors, fans or other equipment which has been insulated with vibration-damping material or which has had metal components replaced with plastic or ceramic elements.

This pitting releases small fragments of material into the oil showing up as high particle counts, high ferrous density and wear debris. This promotes accelerated wear on bearings and other moving parts.





Lubrication Analysis is Used to Improve Profitability in Every Major Industry in the World

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Emerson
Reliability Solutions
835 Innovation Drive
Knoxville, TN 37932 USA
+1 865 675 2400

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