TCR Advanced Engineering P. Ltd

Experts in Metallography, Failure Investigation and RLA

Metallurgy for Industries

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Ferrography

An introduction

Ferrography — What is it all about?

This is a technique in use since 1970. It provides Microscopic Examination and Analysis of Debris (particles) found in lubricating oils. These particles consist of metallic and non-metallic matter. The presence of metallic particle is a wear condition that separates different size and shapes of metallic dust from components like all type of bearings, gears or coupling (if lubricated in path). Non-metallic particle consists of dirt, sand or corroded metallic particles.

Analytical ferrography is one amongst the most powerful diagnostic tools in oil analysis in tribology. When implemented correctly it provides useful information on machine under operation. Yet, it is frequently excluded from oil analysis programs because of its comparatively high price and a general misunderstanding of its value.

The test procedure is lengthy and requires the skill of a trained analyst. As such, there are significant costs in performing analytical ferrography not present in other oil analysis tests. But, if time is taken to fully understand what analytical ferrography unfolds, the benefits in no uncertain terms significantly outweigh the costs and one I inclined to opt it automatically and incorporate it when abnormal wear is encountered.

Additionally, a lub system performance may be improved through proper filtration of oil. Clean oil lubrication is always more effective. Frequent oil replacement is expensive. A rapid centrifuged and/ or magnetic separator cleaning system helps cost cutting and disposal of used oil, as well. Ferrography also helps improving filtration efficiency and frequency for oil cleaning systems.

What type of debris do we expect which are harmful to Lubrication System and the Machine?

There are six basic particle types generated through the wear process. These include metallic particles that comprise of Normal Rubbing Wear, Cutting Wear Particles, Spherical Particles, Severe Sliding particles, Bearing Wear Particles (Fatigue Spall Particles, Laminar Particles) and Gear Wear (Pitch Line Fatigue Particles,

Microstructure of the Month

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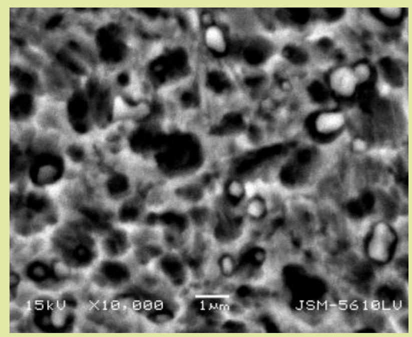


Magnification: *10000X*

Etchant: *Villela's Reagent*

Component: *Vacuum Hardening & Sub-Zero Heat-Treatment Sample*

MOC: *Martensitic stainless steel (X46Cr13)*

Observation: SEM image shows fine tempered martensite structure with rounded alloy carbides at the facets of martensite regions. Fine precipitations of eta carbides are observed evenly distributed in the microstructure.

Useful Hint: Presence of eta carbides would improve the wear resistance and stability of the microstructure.

Scuffing or Scoring Particles)
There do exist sand and dirt particles that accrue wear particles in the system.
The particles are classified to determine the type of wear and its source.

White nonferrous particles, often aluminum or chromium, appear as bright white particles. They are deposited randomly across the slide surface with larger particles getting collected against the chains of ferrous particles. The chains of ferrous particles typically act as a filter, collecting contaminants, copper particles and Babbitt.

Copper particles usually appear as bright yellow particles but the surface may change to verdigris after heat treatment. They will be randomly deposited across the slide surface with larger particles resting at the entry point and gradually getting smaller towards the exit point of the slide.

Babbitt particles consisting of tin and lead, appear gray, sometimes with speckling before the heat treatment. After heat treatment of the slide, these particles still appear mostly gray, but with spots of blue and red on the mottled surface of the object. After heat treatment these particles tend to decrease in size. Again, these nonferrous particles appear randomly on the slide, not in chains with ferrous particles.

Contaminants are usually dirt (silica), and other particulates which do not change in appearance after heat treatment. They can appear as white crystals and are easily identified by the transmitted light source i.e. they are somewhat transparent. Contaminants appear randomly on the slide and are commonly silhouetted by the chains of ferrous particles.

Fibers, typically from filters or outside contamination, they are long strings that allow the transmitted light to shine through. Sometimes these particles can act as a filter, collecting other particles. They can appear anywhere on the ferrogram; however, they tend to be washed towards the exit end.

Ferrous particles can be broken down into five different categories- high alloy, low alloy, dark metallic oxides, cast iron and red oxides. Ferrous particles are identified using the reflected light source on the microscope. Transmitted light will be totally blocked by these particles.

High Alloy Steel - particles are found in chains on the slide and appear gray-white. The distinguishing factor in the identification between high alloy and white nonferrous is the position on the slide. If it is white and appears in a chain, it is deemed to be high alloy. Otherwise, it's considered white nonferrous.

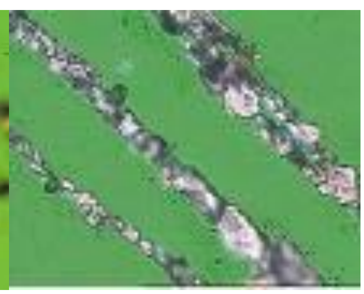
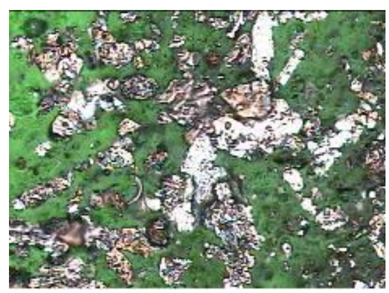
Low Alloy Steel - particles are also found in chains and appear gray-white, but they change color after heat treatment. After heat treatment they usually appear as blue particles but can also appear pink or red.

Dark Metallic Oxides - deposit in chains and appear dark gray to black. The degree of darkness is indicative of the amount of oxidation.

Cast Iron - particles appear gray before heat treatment and a straw yellow after the heat treatment. They are incorporated in chains amongst the other ferrous particles.

Red Oxides (Rust) - polarized light readily identifies red oxides. Sometimes they can be found in chains with the other ferrous particles, and often they are randomly deposited on the slide surface. A large amount of small red oxides on the exit end of the slide is generally considered to be a sign of corrosive wear. It usually appears to the analyst as a "beach" of red sand.

Following are the images of few wear particles.

How the test is conducted?

Analytical ferrography begins with separation of the wear particles by magnetic separation from the lubricating oil containing the wear debris on a ferrogram slide maker. The lubricating oil sample is diluted suitably with organic solvent to improve particle precipitation and adhesion. The diluted sample is allowed to flow from a glass slide called a ferrogram. The ferrogram rests on a magnetic bed, which attracts ferrous particles out of oil.

Due to the magnetic field, the ferrous particles align themselves in chains along the length of the slide with the largest particles being deposited at the entry point. Nonferrous or nonmagnetic particles and contaminants, unaffected by the magnetic field, travel downstream and are randomly deposited across the length of the slide. The deposited ferrous particles serve as a dyke in the removal of nonferrous particles. The absence of ferrous particles substantially reduces the effectiveness with which nonferrous particles are removed.

After the particles are deposited on the ferrogram, a wash is used to remove any remaining lubricant. The wash quickly evaporates and the particles are permanently attached to the slide. The ferrogram is now ready for optical examination using a bichromatic microscope. Samples are examined under a microscope that combines the features of a biological and metallurgical microscope. Such equipment utilizes reflected and/or transmitted light sources. Different optical filters are deployed to classify sizing, composition, shape and texture of the particles.

After classifying the composition of particles the analyst then rates the size of the particles using a micrometer scale on the microscope. Particles with size of 30 microns or greater are given the rating of “severe” or “abnormal.” Severe wear is a definite sign of abnormal running conditions of the equipment being studied.

How to take Advantage of this concept?

Ferrography is a series of laboratory tests used to determine the condition of used Lubricants and equipment components, over a period. A trend of Wear Particle Concentration typically presents the opportunity for Maintenance programs from breakdowns to be proactive. The wear particles are either generated or captured in system through atmospheric dust/ dirt. The particles generated due to friction despite proper lubrication is an indication of damage to the system component. For example wear on gear teeth results in improper meshing, that means over a long period of such operation machine tends to consume more power for same throughput. Further operation under same loading condition leads to vibration, followed by noise radiation. A regular vibration-monitoring programme can capture higher vibration at the later stage of damage condition. More is the damage, more is the release of particles from component; thereby increasing the concentration of wear particles in lubrication oil tank. The choking of filters is next stage when operator comes to know impending failure.

Regular monitoring of WPC (Wear Particle Concentration) thus alerts an operator earlier than any other damage symptoms. This in fact helps maintenance engineer to schedule machine overhaul and / or be prepared for spares & replacement.

What Benefits do I expect?

- Reduction in unscheduled downtime due to wear of rotary components like bearings and gears
- Effective maintenance scheduling
- Improved equipment reliability and safety
- Reduction in maintenance costs
- Maximization of oil change-out intervals that indirectly conserves environmental cleanliness.
- Reduction in machine power consumption over a period

How much and from where the Oil samples are to be drawn?

This really is a question of debate for critical equipment running on low quantities of lubricants. A tank capacity beyond 20 liters can be planned to tap 100 ml of oil every 3 to 4 months. Typically two oil samples are to be taken from a lubrication path- first, after filter and second before entering to oil tank / reservoir. However, it needs to be ascertained to drain accumulated oil on sampling point before collecting actual representative sample. Normally, to draw 100ml of oil sample 50 to 100ml of oil need to be drained off. Total oil loss is attributed to 1.5 liters per year. This may simply be topped up for tank capacities under 20 liters.

Once the ferrography adopted, the results of each analysis predict next sampling time, thereby sampling periodicity is scheduled. Increasing wear particle concentration triggers higher sampling frequency to determine machine health assessment.

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