**LUBRICANT SAMPLING, ANALYSIS AND TEST IN PREDICTIVE MAINTENANCE**

by

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Used oil analysis is the bottom line for a successful maintenance strategy. Lubricants are the lifeblood of all machinery and an essential element of predictive maintenance technologies and may be described as a blood test for the machinery. In service oil sampling, analysis and testing can provide, *inter alia*, trace information about machine wear conditions, lubricant contamination and general condition. See the Figure below. Diagnostic and maintenance engineers, using oil test analysis results, can make important maintenance decisions among which are the immediate benefits of avoiding the mixing of oils, contamination control, condition based maintenance and failure prediction.

 Machine Wear

 ?

 Change Oil?

 Change Filter?

 Scrap?

 Lubricant Lubricant

 Degradation Contamination

**Lubricating Oil Analysis and Choice Diagram**

Machine condition monitoring and/or predictive maintenance is the practice of assessing a machine’s condition by periodically gathering data on key machine health indicators to determine when to schedule overhaul and maintenance. One of the keys to keeping machinery operating at optimal performance involves monitoring and analysing lubricant oils for characteristics such as contamination, chemical content and viscosity. A vast amount of money is spent annually replacing machinery components that have worn out due to the inability of the lubricants to perform their required task. Knowing how to interpret changing lubricant properties is the task of the diagnostic and maintenance engineer and can increase both the working time and the life of often highly critical capital equipment. The existence or amount of debris and particles from wearing parts, corrosion, erosion and contamination, provide clear information about the issues affecting performance and reliability. Lubricant and other key fluid analyses provide critical early warning information indicative of machine failure. Analysing and trending the data means maintenance can be scheduled before a critical failure occurs. The result of such good practice is higher equipment availability and productivity, lower maintenance costs, lower total cost of ownership, less downtime, optimal equipment performance and a greener operation.

**Common In Service Oil Analysis Techniques**

The author’s experience has been confined to the marine field but this paper, although marine orientated, applies equally well to land-based machinery.

The table below shows typical oil analysis parameters and common analytical techniques to monitor machine wear, contamination and degradation.

**Key oil analysis parameters and corresponding analytical techniques**

|  |  |  |
| --- | --- | --- |
| **CATEGORY** | **KEY ANALYSIS** | **ANALYTICAL TECHNIQUES** |
| **Machine wear** | Fine wear metal elements | Rotating Disc Electrode (RDE) Spectroscopy, Inductive Coupling Plasma (ICP) Spectroscopy |
| Large wear metal elements | Rotrode Filtration Spectroscopy (RFS), FPQ, XRF |
| Particle count and distribution | Particle count, Laser Net Fines (LNF) |
| Wear particle shape analysis | LNF, Ferrography, Wear Debris Analysis (WDA) |
| **Contamination** | Sand and Dirt | Particle count, Laser Net Fines (LNF) |
| Fuel Dilution | Fuel Sniffer, Gas Chromatography (GC) |
| Water/Moisture | Infrared (IR), Karl Fischer Titration (KF) |
| Glycol/Coolant | Infrared Spectroscopy |
| Soot | Sootmeter, Ir |
| Alien Fluid | IR |

It is always good practice to advise relevant personnel to require oil samples to get an idea of the status of wear on machinery. If the person accepts that advice, the diagnostic or maintenance engineer should further advise his client, he has a subject clause his next moves of “subject to a favourable oil analysis”. Should he not avail himself of such advice the engineer will have closed off any avenue of legal action against himself.

Any machine is kept running smoothly by the addition to the sump of lubricating oil. This is pumped around inside the engine by means of an oil pump which is usually mechanically driven and inside the sump and the oil passes through a filter, over every bearing and down each cylinder wall. The oil is kept at a reasonable working temperature by-passing through a heat exchanger which is often fitted in tandem with the cylinder jacket water heat exchanger. The actual arrangement varies from engine type to engine type and from manufacturer to manufacturer. By-passing through the engine in this manner the oil takes into a loose solution of tiny particles of wear metal from the bearings and combustion particles from the cylinders. In carrying out a full survey on any machine, the diagnostic engineer should, when he is looking at the engine, check and report on the condition of the lubricating oil. The nature of the contamination or any effects it may have had on the engine cannot be accurately determined by this method but carrying out this test will certainly give the engineer confidence in suggesting that a detailed chemical analysis of the oil be made, and any recommendations of the analysing laboratory be accepted.

There are two main reasons for removing oil from service, and they are respectively: -

1. pollution from outside sources, and
2. oxidation causing deterioration of the oil itself.

High water content is possibly an exception. On some plants it would be removed simply by centrifuging the oil, but such a process is not usually available on smaller installations and, if excess water is found, the diagnostic and maintenance engineer should at least suggest that the oil should be changed. For detergent oils, a third reason for changing the oil may be added in *i.e*. a high insolubles content as that causes a depletion of the detergent additive.

Oil samples should be taken and analysed annually and at least three samples should be taken at each investigation; one either side of the filter and a minimum of one from the machine’s sump.

Lubricating oil analysis (LOA) is the laboratory analysis of a lubricant's properties, suspended contaminants and wear debris. It is a quick non-destructive method of gauging the health of an engine by taking a close, specialised look at what is in the oil and should be performed as part of a routine preventative maintenance scheme to provide meaningful and accurate information on the lubricant and machine condition. By tracking oil analysis sample results over the life of a particular machine, trends can be established which can help eliminate costly repairs and down time.

The diagnostic or maintenance engineer should be aware, however, that receiving a warning from a single sample is not necessarily indicative of a machine performance issue and he should know that it’s extremely important to examine all test results from a given sample in order to be able to decide what is happening. An acid number (AN) test, for example, may give off a warning but, by itself, that does not provide any meaning full insight into how the machine under test may be performing. The engineer needs to consider the relevance of the test when making any maintenance decision and, in relative importance, he should also consider viscosity, oxidation, nitration, the presence of wear metals and the base number (BN) in order to truly understand whether or not the lubricant is performing as well as it should. Reliance on one factor such as the acid number may well lead to erroneous results. It does not mean that the lubricant is underperforming. Consistent monitoring of the complete analysis results trend over time are, therefore, essential and become an effective tool to enable him to understand what is happening inside the machine. As another example, when a series of particular compression ignition engines were tested over a long period, a consistent warning was found on copper wear metal. Investigation showed, however, that a number of the engines had undergone significant design and component changes. It was agreed, therefore, that the testing programme had to adapt to changes that affected the limits applied in order properly confirm the actual engine condition. That showed that a single copper waning did not necessarily indicate a performance issue and that the trend over time needed to be considered to see if the copper wear figures increased in the studied period.

When the diagnostic or maintenance engineer is analysing the results of a used oil sample, as well as the metallurgy of the machine’s components, he should also consider the chemical formulation of the lubricant itself. Occasionally, the lubricant’s own components may give warning signs for certain tests. For example, some oils are formulated with zinc based additives which may indicate that metal wear test results including copper tests to seem abnormally high. If such a result appears, then the analyst and engineers should make a more detailed study to see whether the copper is actually entering the lubrication system or whether components in the oil are the direct cause of the warning.

Perhaps the worst major challenge for a number of industrial machines is the presence of water. As a result, it is usual to look for water with a special test. On site, a simple hot plate or crackle test may be used but in a lab the Karl Fischer test is applied. The crackle test only tells the investigator that water is present but not by how much. The Karl Fischer test gives the investigator the quantity in a given sample and so provides more insight into how badly the lubricant is suffering from too much water. It is good practice to carry out a crackle test on site before taking a sample to the lab for a full, in depth Karl Fischer test.

**Lubricating Oil on Site Tests**

The diagnostic or maintenance engineer should pull out the dipstick and check that there is sufficient oil in the sump by reading the oil level against the marks thereon. It should be noted that lubricating oil in a compression ignition engine is always black and, in a petrol engine, a dull yellowy-brown colour. He can then make some simple on site tests to check the quality of the lubricating oil in the sump. There are three of these tests: -

* the feel test.
* the drop test.
* the crackle test.

*The Feel Test*: For this test, he should rub the sample on the end of the dipstick between thumb and forefinger. The oil should feel smooth to the touch. If there is anything wrong with the lubricating oil this will be instantly discovered as it then will feel gritty.

*The Drop Test*: If he feels this grittiness between his thumb and fore finger, the diagnostic or maintenance engineer should then see if the oil requires further analysis by making a simple drop or dispersions test. The drop test provides quick and accurate visual confirmation that it is time to change a lubricant. Further, if the results of such a test are compared at regular intervals, oil change cycles can be determined for the particular engine, brand of oil and their use, all of which affect oil degradation. This test is carried out by stretching a filter paper tightly over the top of a convenient tin or other receptacle and held in place by means of an elastic band and then dropping a blob of the oil onto the filter paper and leaving it to spread. Over a short period of time, the oil slowly spreads out over the surface of the paper and drips through leaving any contamination behind as a series of coloured, concentric rings. A fresh sample of oil should be dropped onto the paper at the same time as the sample being tested for comparison purposes. The procedure is simple: -

* Withdraw the engine or gearbox dipstick and allow a generous drop to form on the end. Deposit the oil drop on the test sheet by lightly touching the end of the dipstick on the medium.
* Leave the test sheet in a horizontal position for a few minutes and then compare the sample to a sample of clean unused oil similarly treated.
* Backlighting samples enhances the sample results. This is done by simply holding the sheet up to a light or the sky.

*The crackle test*: This test has been used as a reliable indicator of emulsified water, a go/no-go test. However, with practice and keen eyes and ears, the procedure can be advanced considerably and made more quantitative. Rather than simply listening for the crackle (which is due to scintillation), by adding visual observation of vapour bubbles, a rough indication of the amount of moisture present can be obtained. The revised method is referred to as the visual crackle. Success in using the procedure depends on practice with varying moisture concentrations in different common fluids. A laboratory syringe and a paint shaker can help create the experimental suspensions. While the visual crackle does not replace the need for other more precise techniques, it does provide vital information when and where it is needed. Simple, inexpensive on site tests such as this can make a real difference in the effectiveness of oil analysis and contamination control.

*The hot plate crackle test* is a simple test to identify the presence of free and emulsified water suspended in the oil, provided a few simple rules are followed.

1. Raise the hot plate temperature to 320°F (160°C). Always use the same temperature.
2. Violently agitate the oil sample to achieve an homogenous suspension of water in the oil.
3. Using a clean dropper, place a drop of agitated oil on the hot plate.

The diagnostic or maintenance engineer should look for the following: -

1. If no crackling or vapour bubbles are produced after a few seconds, no free or emulsified water is present.
2. If very small bubbles (0.5 mm diameter) are produced but disappear quickly, approximately 0.05 to 0.10 percent water is present.
3. If bubbles of about approximately 2 mm diameter are produced, gather to the centre of the oil spot, enlarge to about 4 mm, then disappear, approximately 0.1 to 0.2 percent water is present.
4. For moisture levels above 0.2 percent, bubbles may start out about 2 to 3 mm then grow to 4 mm with the process repeating once or twice. For even higher moisture levels, violent bubbling and audible crackling may result.

He should be wary of the presence of dissolved gases, fuel, refrigerants and volatile solvents, which can cause false positives.

Although generally applicable, the crackle test does have some limitations.

1. The method is non-quantitative.
2. Hot plate temperatures above 320°F (160°C) induce rapid scintillation that may be undetectable.
3. The method does not measure the presence of chemically dissolved water.

The crackle test can be performed with a minimum of investment using the following equipment: -

1. A hot plate capable of achieving and maintaining 320°F (160°C) surface temperature.
2. A paint shaker (or equivalent) for oil agitation.
3. An oil dropper tube or laboratory syringe.

**WARNINGS**

The diagnostic or maintenance engineer should know that all oil has to be considered as hazardous and he should avoid oil contact with his skin, eyes and mouth and a sample should never be taken from an engine that is running.

He must exercise extreme caution when performing the crackle test on oils that might contain hazardous gases or low boiling point volatiles which might produce fumes and vapours that present inhalation and/or serious skin or eye injury upon contact. When evaluating these oils, the hot plate should remain under a vent hood that allows the analyst to conduct the test without coming into contact with fumes or vapours.

The analyst must wear protective eye goggles, gloves and a long sleeved overall. The test must be performed in a well ventilated area.



