

Oil and Wear Particle Analysis

BENEFITS

Each business has different reasons for implementing an oil analysis program. We understand these reasons, and tailor our oil analysis programs to meet your needs. In order to best match the requirements of an oil analysis program for any business. We have developed unique oil analysis services for the different sectors in which lubricated equipment operates.

Our oil and wear particle analysis packages cover areas of analysis. An assessment of the oil condition reveals whether the system oil is ready to be changed, or if it is fit for further service. Save money by maximizing your oil change out intervals with the confidence that condition monitoring provides. Detection of ingress of contaminants from the manufacturing environment, including process contaminants, dirt, and water alerts you in time to perform filtration service, saving the oil and avoiding unnecessary wear. When routine monitoring reduces the oil condition and contamination, system wear will be minimized. Our analysis can detect subtle changes in the levels of wear metals present in the system oil. Failures due to worn out components can be avoided long before those components are worn out of specification.

The Benefits of Oil and Wear Particle Analysis are:

- Reduction in unscheduled downtime
- Effective maintenance scheduling
- Improved equipment reliability
- Reduction in maintenance costs
- Maximization of oil change out intervals
- Minimization of installation errors
- Reduction in machine power consumption

Oil analysis service detects abnormal equipment condition before that equipment runs into costly repairs, with time to schedule corrective action. This reduces the cost of your repairs. Problems are caught early, minimizing unscheduled, costly downtime. We help you to extend the life of your valuable investment. Our oil analysis program only requires you to take a small sample of the oil from each component being monitored. You are provided with clear and concise directions, forms and sample bottles needed to submit samples to the laboratory.

WEAR

Wear means the loss of solid material due to the effects of friction of contacting surfaces. It is generally harmful, although in some cases it can also be beneficial, for instance during the running in of an engine. The deterioration of the surfaces in an engine is generally due to isolated or simultaneous mechanisms, among which we can distinguish the following.

Adhesive wear

This occurs as a result of metal-to-metal contact, due to overheating or insufficient lubrication. This in turn causes the formation of micro welds, with often a subsequent deposition of soft metal onto heavy metal (e.g., aluminum onto iron, lead onto steel). Consequently, there is a shearing of the junctions and a transfer of metal particles.

There are two types of adhesive wear - heavy, liberating relatively large metal particles (50 to 200 microns), called 'scuffing', and eventually leads to a failure of the engine; and moderate - the formation of very small metal oxides which is termed 'soft' or 'normal adhesive' wear. Adhesive wear can be avoided by the use of an appropriate lubricant containing extreme pressure (EP) additives, and the choice of the correct viscosity oil.

Abrasive wear

This form of wear results from the grooving of a surface by hard asperities or by particles of rust or dust which have entered the oil. When these particles are very small, the phenomenon is known as 'abrasive erosion' (which is especially the case in hydraulic systems). Abrasive wear can be avoided by eliminating potentially abrasive particles through filtration.

Corrosive wear

This is chemical or galvanic attack, followed by the removal of the reaction products (chemical complexes) by mechanical action (friction). It can be avoided by the use of effective materials, also by the use of neutralizing additives in the oil. Changing the oil in time may also minimize it.

Wear by fatigue

This means the removal of spoiled away particles by fatigue resulting from contact, aided by vibration, high pressure, high temperature and other aggressive conditions. This type of wear may be reduced by re-equilibration of the system.

Contact corrosion (fretting corrosion)

Corrosion due to contact means the removal of material between two surfaces, which are in almost static contact but subject to mechanical vibration, and oscillation. Consequently, there is oxidation of certain particles. Thus, for iron materials, there is an accumulation of 'red powder'. An example of this is the bearings of cars transported by railway.

Erosion by cavitations

The formation of cavities by entrainment of air or gas bubbles present in the fluid in movement is a destructive phenomenon, which can provoke the removal of material particles.

Wear of electrical origin

This refers to the erosion by sparks, produced by inadequate electrical insulation in motors of alternators.

CONTAMINATION

The causes of oil contamination are many, and can be classified according to source. Thus there is contamination coming from outside the system - dust (silica); liquids (mixture with other oils, water, other contaminated oil). The second is in open systems - chains, cables, and gears in contact with dust, water, and so on. The third is in closed systems.

Impurities can also come from the settings and processes in which the lubricants work, e.g. manufacturing can produce welding debris, assembling involves dust, perhaps also silicones or polishing powder, while maintenance can introduce impurities via dirty rags or deteriorated joints, and lubrication systems may need or involve aspiration, or open tanks.

The lubricant itself can produce or contain contaminants - wear, sludge (deterioration of the oil), soot, acids (oxidation of the oil, sulphur from fuel), temperature changes or extremes, fuel, anti-freeze, deterioration of packing and seals (e.g. deteriorating through the action of synthetic oils or brake fluids).

The type of contamination can vary according to the source. Thus dust, for example, can arise within a shipyard as sand, i.e. Si, Al. In metallurgy, one can find the oxides of iron. On a ship, there are problems with salt water. Industrial and automotive settings are filled with potential contaminants, for example chemical products, or coal powder. Liquid contaminants can include water, acids, solvents, anti-freeze.

OIL CONDITION

Oils undergo destructive changes in property when subjected to oxygen, combustion gasses and high temperatures. Viscosity change, as well as additive depletion and oxidation occur to degrade the oil.

Additive Depletion

Oil additives also have a limited lifetime. Some are consumed as oil ages. For example, neutralizing corrosive acids produced by the combustion process uses up alkaline additives. When the oils reserve alkalinity (TBN) falls below the minimum safe level, higher component wear can be expected.

Make-up oils will increase oil reserve alkalinity only to the extent of the new oil added and has no neutralizing reaction on existing oil acid levels.

Rust and corrosion inhibitors, anti-oxidants and film strength agents also reach a point when they can no longer carry on. Additive "dispersants" suspend contaminants, deposits and other combustion insolubles until they are removed from the system by oil and filter change out.

Once a dispersant becomes "loaded" any added sludge, resin or soot will cause the oil to dump whatever it has collected... and refuse to collect anymore. This results in a rapid build-up of engine deposits.

Oxidation

All engines, transmissions and drive-axle component oils oxidize. A chemical reaction between oil molecules and oxygen takes place at high operating temperatures. This reaction increases viscosity, causes formation of insoluble engine deposits and corrosive acids which further increases component wear.

Higher operating temperatures, fuel consumption, rapid additive depletion and substantial loss of power can also be expected when oil oxidation takes place. When severe, oxidation makes the oil very hard to pump causing lubrication starvation to moving parts, with inevitable results. Oils that are oxidized have a very pungent, sour odor.

OIL ANALYSIS TESTS

Several methods are used to analyze oil condition and contamination. These include spectrometry, viscosity analysis, dilution analysis, water detection, Acid Number assessment, Base Number assessment, particle counting, and microscopy.

Spectrometry

A spectrometer is an instrument with which one can measure the quantities and types of metallic elements in a sample of oil. The operating principle is as follows. A diluted oil sample is pulverized by an inert gas to form an aerosol, which is magnetically induced to form a plasma at a temperature of about 9000°C. As a result of this high temperature the metal ions take on energy, and release new energy in the form of photons. In this way, a spectrum with different wavelengths is created for each metallic element. The intensities of the emissions are measurable for each such element by virtue of its very specific wavelength, calculated in number of ppm (parts per million). An ICP spectrometer can detect the very small metal particles in suspension in the oil, i.e. with a size between 0 and 3 microns.

Those small particles are a good indication of general wear, except in cases of sudden metallic rupture, where there will be relatively more large particles liberated (50 microns and more). The human eye can detect particles of a size starting from 50 microns, which allows them to be visualized using more conventional means. Thus, complementary analysis

of such larger particles can be done by spectrometry (after acid attack), by ferrography (or related systems) or by optical or electronic microscopy.

Viscosity (Engine oils)

In the early days of the IC engine there were only monograde oils (e.g., SAE 20, SAE 30, SAE 50). By putting an additive into these oils, called a VI improver, multigrade oils were created. The VI (viscosity index) improver is a flexible molecule, rolled up like a ball at low temperature and stretched out like a string at high temperatures. This allows the oil to remain viscous at high temperatures. One can recognize multigrade oils as being represented by two figures. The first figure, followed by the suffix 'W', stands for the viscosity class at low temperature (W = winter). The second figure is the SAE class at working temperature. Thus, for example, 'SAE 20W-50' means that the viscosity of the oil at low temperature corresponds with a SAE 20W, and the oil viscosity at 100°C corresponds with a SAE 50. The table below gives some data on viscosities.

The viscosity of used engine oil is mostly measured at 100°C, and can drop for reasons of fuel dilution, and/or shearing of the VI improver. Viscosity can increase as a result of heavy contamination of the oil by soot, and/or oxidation of the oil.

Viscosity (Industrial oils)

The viscosity of industrial oils, by contrast, is mostly measured at 40°C, and must correspond with the ISO table below, i.e., the viscosity of an ISO class oil must be within the minimum and maximum for that class. (Moves are in hand to make the viscosity class statement contain more data, to reflect changes in the oil in use.)

The viscosity can be decreased by adding more fluid oil, or as a result of high water content, or by shearing of the VI-improver. The viscosity can be increased by adding more viscous oil, and by oil oxidation (e.g. as a result of overheating).

Dilution

Dilution of use engine oil can be measured precisely by gas chromatography (GC) or by Fourier Transform Infrared spectroscopy (FTIR). More common is the use of the SETA-FLASH tester, where a certain temperature tests the flash point of oil. When a flashpoint is detected, the dilution is heavy (more than 4%), when not, the dilution is acceptable (less than 4%).

It is evident that heavy dilution of the oil is unfavorable for the engine, since it involves a lower viscosity and reduces the resistance of the oil film. The principal causes of dilution are a defective fuel injection system, a defective air inlet (obstructed air filter), incomplete combustion due to too low a working temperature, and badly regulated valves, or insufficient compression.

Water detection

The water-content of the oil is usually measured by the Aqua test or a Karl Fisher apparatus. The possible causes of water introduction include (a) condensation, due to too low a working temperature, defective crankcase ventilation, 'stop and go' in-service usage, and obstruction of the exhaust system; or (b) infiltration, due to leakage at the cylinder head gasket, or damage of the engine block.

Cooling water contains most often an anti-freeze based on glycol. Therefore a glycol test should be performed when water infiltration is suspected. The inhibitor in the anti-freeze agent is usually a sodium borate type.

Acid Number (AN)

The acidity of the oil is measured by titration through a base, and expressed in mg KOH/g. The figure below shows this graphically, showing the evolution of TAN as a function of time.

Base Number (BN)

The alkalinity of an oil is measured by titration through an acid, and expressed in mg KOH/g. The comparison between the TBN volume of the fresh oil and that of the used oil allows the determination to be made of whether the used oil is still capable of neutralizing acid residues. These acids are produced by combustion (sulphur in fuel) and oxidation of the oil and oil additives. When the oil is in service too long, the TBN will drop significantly.

Too low a TBN volume can be due to: heavy oxidation of the oil, when the oil has been in service for too long, of the oil level was insufficient, or due to a defective cooling system, producing overheating; use of a fuel containing a high sulphur content; use of an inappropriate lubricant; or contamination of the oil by fuel or water.

Particle Counting

This is an especially useful test for a hydraulic system with high sensitivity (e.g., servo-valves). In such a test, a certain quantity of hydraulic oil flows through a sensor, where all the insoluble material in the oil is detected and counted using the principle of light absorption. The particles counted are classified cumulatively:

>5 μ ; >15 μ ; >25 μ ; >50 μ ; >100 μ .

Or differentially: >5-15 μ ; >15-25 μ ; >25-50 μ ; >50-100 μ ; >100 μ .

The results of particle counting can be expressed according to either ISO 4406 or NAS 1638. According to ISO 4406, the results are expressed cumulatively, and the ISO classification is deduced from the two first classes, >5 μ and >15 μ .

According to NAS 1638, the results are expressed differentially, in five classes. In each class one can get a NAS quotation, and the NAS code is the figure given to the first class.

Microscopy

After filtration of a certain amount of oil through a cellulose filter (of 0.8 μ), the filter is examined under an optical microscope (magnitude 100x, 200x), and one is able to distinguish:

- white or brilliant metal particles (demonstrating recent wear)
- black metal particles (already oxidized)
- rust particles
- silt (i.e., very small particles below 5 μ , responsible for erosive wear)
- silica (sand, dust)
- polymers (from oil additives)
- welds
- paint flakes
- other impurities (fibre, plastics, and so on)

INTERPRETATION

The critical factor in oil analysis is the interpretation of the oil analysis results. A diagnostician interprets the oil test results and produces a concise summary of the equipment, and oil condition.

Diagnosticians draw from many sources to produce a valid interpretation of oil analysis results, including OEM wear limits, oil baselines and typical, industry literature, but most importantly a diagnostician draws upon their experience and mechanical expertise to correctly interpret test results into a correct picture of equipment condition.

The oil analysis interpretation includes a discussion of the equipment wear state, level of oil contamination, and oil condition and includes a recommendation outlining any corrective maintenance actions that are necessary.