Oil—How Clean Does It Have To Be?

Oil cleanliness has a major effect on wear within equipment.

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Clean, dry oil can extend equipment life between failures up to 8-10 times the normal operating life. The Timken Co., a bearing manufacturer in Canton, OH, reports that reducing water levels from 100 ppm to 25 ppm increases bearing life two times. British hydraulics research indicates that if solids contamination with particles larger than 5 micron is reduced from a range of 5000-10,000 particles/ml of oil to 160-320 particles, machine life is increased five times.

It is clear there is great benefit to be gained in having clean oil and that it may well be worth spending a lot of money to achieve it. This would be the case where expensive equipment was used and the cost of maintenance was high or where the equipment was costly but not highly profitable to operate. Increasing the equipment life and the period between maintenance up to 10 times normal would be highly profitable in both cases. On the other hand, if the cost of replacement equipment is inexpensive, it is unlikely to be justifiable to spend money on oil filtration.

TABLE 1. ALLOCATION OF PARTICLE COUNT SCALE NUMBERS

	Particles per milliliter	
ISO Scale Number	More than	Less than
22	20000	40000
21	10000	20000
20	5000	10000
19	2500	5000
18	1300	2500
17	640	1300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.25	2.5

Grading oil cleanliness

Solid particle counts in oil can be done with optical equipment (microscope, light extinction), with an electron-scanning microscope (ESM), or by sifting through screens. Each procedure produces slightly different particle counts due to the varying sensitivity in detecting particles of different sizes. The ESM detects many more smaller particles than the optical methods.

Counting standard ISO 4406-1999 is used internationally to rate solids contamination of oils. This standard classifies the cleanliness of oil and provides a basis to define acceptable solids contamination. It also means oil filters can be tested to prove their performance meets acceptable standards. Table 1 is part of the ISO 4406 method of coding the level of solid particles in an oil sample. The solid particle content of oil gets a classification that represents the number of particles of a particular size range.

Where calibrated automatic counting devices are used to measure contamination, three scale numbers are used to describe solids contamination: 4 micron and larger, 6 micron and larger, and 14 micron and larger. When the count is done by optical microscope two size ranges are used: 5 micron and larger and 15 micron and larger.

For example, oil solid particle contamination can be described as ISO 20/18/16. This means there are between 5000 and 10,000 particles larger than 4 micron/ml sample. Also there are between 1300 and 2500 particles larger than 6 micron/ml of sample and between 320 and 640 particles larger than 14 micron. If a two-scale number is used, the contamination result could be 18/16. In this case there are between 1300 and 2500 particles larger than 5 micron/ml of sample and between 320 to 640 particles larger than 15 micron.

Contaminated oil destroys equipment

Dirty oil spells rapid death for hydraulic machinery and lubricated equipment. Fine tolerance equipment can have clearances between parts of 5-10 microns. Solid particles larger than the clearance gap will jam into the space. The solid particles will be further broken up and mangled while ripping out more material from the surfaces.

In equipment with larger tolerances, the oil film between parts can get as thin as 3-5 micron. Solid particles larger than the oil film will be broken up into smaller pieces and produce more solids contamination. Fig. 1 shows a shaft in a journal bearing lubricated by oil. In the drawing, the solid particles are larger than the oil film thickness and when they enter the bearing pressure zone at the bottom of the shaft they will tear into the metal, be broken up, and make more particles that cause further wear.

Solids suspended in oil are like grinding paste. They scour and gouge surfaces, block oil passages, and make the oil more viscous. The longer the oil is left dirty, the faster the rate of failure. Even expensive synthetic oil is of no use if it is contaminated by solid particles. Though synthetic oil has better high temperature and surface tension characteristics than mineral oil, all advantages are lost if the synthetic oil is so contaminated that it is destroying the machine. The only solution is to keep the oil clean by filtration.

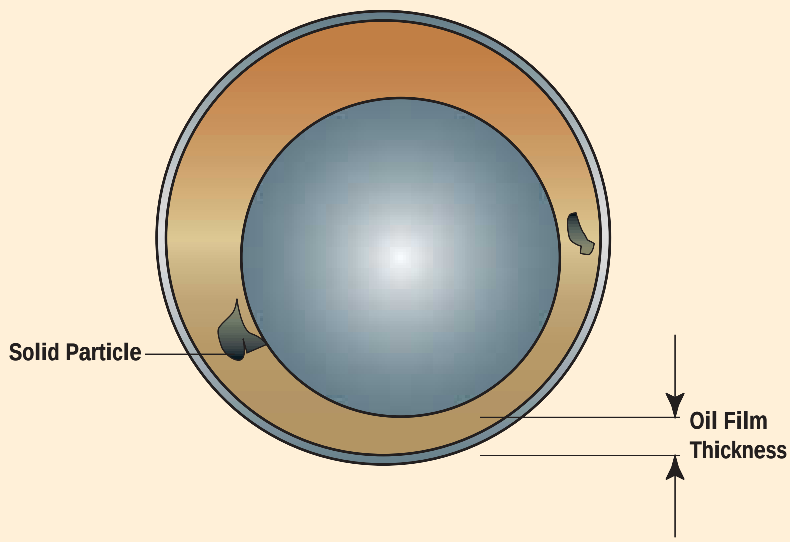

Fig. 1. Solid particles in bearing oil film.

Oil analysis measures contamination

Oil samples can be taken and analyzed in a laboratory. The analysis can measure a large range of parameters and factors that influence oil quality. Typically these include tests that quantify:

- The number and size of particles.
- The types and quantity of contaminants present.
- The condition of the additives in the oil.
- Changes to oil chemistry caused by the working environment.
- The amount of water present.
- The viscosity of the oil (slipperiness).

It is not necessary to do all tests on all oils in all situations. The selection of the type of analysis depends on the oil and where it is used. The oil used in combustion engines, gearboxes, hydraulic systems, and gas turbines is not the same and the conditions under which it operates are different in each situation. For example, soot would be present in internal combustion engines but it would not be present in gearboxes. There is no value in paying money to measure the amount of soot in a gearbox. But the amount of soot in the oil of a diesel engine is of critical importance.

Testing laboratories are required to follow internationally recognized procedures when measuring oil contamination. Equipment used to measure contaminants also needs to be calibrated to recognized international standards. However, just as there are clean and dirty maintenance shops, there are clean and dirty laboratories. Results from laboratories without good calibration procedures and sample hygiene practices or from people who do not fully understand the equipment and procedures should not be trusted.

Not all solid particle counting laboratory equipment can count particles down to very fine sizes. Results from these laboratories would give false figures showing less contamination at low micron sizes than was actually present. Some laboratories use equipment and methods that do not count particles larger than 100 micron. Results from these laboratories would show incorrect large particle counts. In the future, these large particles would be smashed up and broken down, and the resulting smaller particles would quickly contaminate the oil.

If the sample itself is too heavily contaminated, optical counting methods cannot be used because the light emitted by the analyzer will not pass through the sample in the same way the equipment was calibrated to receive. Optical counters can mistakenly count water droplets as solid particles. At times it can be necessary to confirm laboratory results by alternate means to prove the results are reliable.

Sampling cleanliness

The method and cleanliness by which an oil sample is taken has a critical effect on the accuracy of the laboratory results. If the sample is falsely contaminated by taking it from the wrong point or in the wrong way, or if the sample-taking equipment or method introduces contaminants, then false contamination levels will be reported.

A good sample is one that is cleanly taken from the circulating oil flow. The proper sample-taking method and procedure should be agreed with the laboratory and if necessary the laboratory should be asked to provide training for the sample takers.

How clean should oil be?

Many original equipment manufacturers have accepted the indisputable evidence from numerous field and laboratory trials that oil cleanliness has a major effect on wear within their equipment. Some of them are now specifying how clean the oil used in their equipment must be if warranty claims are to be honored.

For example, Caterpillar Inc. specifies new oil to have a particle count of ISO 16/13. If new oil is above this level of contamination it will not warranty the equipment. When new oil from a leading international oil manufacturer was tested before putting it into new Caterpillar equipment, the solid particle contamination was found to be 17/14. This was new oil from a never previously opened container. In this case the new oil had to be further filtered to bring it to below the required specification.

Table 2 is a list of the recommended target oil contamination levels for close tolerance equipment from a survey of hydraulic oil equipment and oil filter manufacturers.

TABLE 2. RECOMMENDED TARGET OIL CONTAMINATION LEVELS

Component	< 3000 psi	> 3000 psi
Fixed displacement pumps		
Vane	17/14	16/13
Gear	17/15	16/13
Piston	16/14	15/13
Variable displacement pumps		
Vane	15/13	-
Piston	15/13	14/12
Valves		
Directional	18/15	17/14
Proportional	16/13	15/12
Servo	14/11	13/10

Oil filtration

For extremely low wear rates and long equipment life, the evidence indicates that oil needs to be filtered down below 5 micron size and preferably down to 1 micron size. Care needs to be taken that the filter does not remove any solid additives, such as graphite, in the oil. Additives dissolved in the oil will not be removed unless the additive is attached to a solid particle.

Oil filtration can be done under full oil flow or with bypass flow or offline. There are several filter types such as pleated paper and wrapped fibre cord. In all cases the filter must capture a large proportion of greater than 5 micron particles if it is to clean the oil.

Filter performance

The correct way to measure filter performance is by use of the Beta Rating, which compares the number of particles entering a filter to the number leaving. It is an accurate way to measure true in-service performance. Nominal filter micron size ratings from manufacturers are meaningless. And absolute filter micron size ratings are unreliable since the softer particles in the oil can be squeezed through the filter and reappear as contaminants.

Numerous tests on a range of hydraulic (e.g., piston pump) and oil-lubricated equipment (e.g., truck engine) have been conducted that confirmed filtering oil and removing particles deliver exceptionally long equipment life. The cost of suitable filtration systems is not expensive. For expensive hydraulic and oil-lubricated equipment the cost of filtration is easily and quickly returned by the large gain in equipment working life and reliability.

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