Understanding Oil Analysis: Viscosity and Particle Count

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Introduction

In this session, you'll gain a more in-depth understanding of two of the most critical oil analysis tests for industrial machinery, Particle Count and Viscosity. You'll hear practical explanations of how particle count and viscosity are measured and reported on an oil analysis report, and you'll also see some side-by-side comparisons of common testing methods and how they compare in benefits and drawbacks with test results. Some techniques for using the test data to spot problems and reveal abnormal conditions will be discussed.

Viscosity, a brief review

To start, let's make sure we all have a few very basic concepts. Viscosity is basically a measure of a fluid's resistance to flow. Data reporting for viscosity is generally reported in cSt, or Centistokes.

Testing is typically performed at two temperatures – 40 degrees Celsius (104 degrees Fahrenheit), and 100 degrees Celsius (212 degrees Fahrenheit). These temperatures are generally accepted to be the norm because they represent the bulk of the operating temperatures available. Lower temperature units such as gearboxes will generally be running far less than 100°C but quite a bit higher than room temperature, and higher temperature units such as engines will be running at or above 100°C.

A final general information bit that should be touched on here is what Viscosity Index is. Viscosity Index, to briefly summarize, is the difference in viscosity at two different temperatures. Most people know that lubricants are less viscous at higher temperatures, but what isn't generally known is that the amount of change is not linear, and Viscosity Index is the test to look at the viscosity change versus temperature. While there will always be a change when going to a higher or lower temperature, the higher your Viscosity Index is, the less pronounced the change will be.

Overview

Viscosity testing equipment will almost always have two main components. One component is a container for the fluid to be tested. This can range from a glass tube to a bulk drum, but there is always going to be something to hold the lubricant during testing. The second component that you will almost always have in some form is a timer. Whether it is a stopwatch or an internal timer, there is generally some way to time the measurement.

Professional Lab Equipment

Lab equipment is generally centered on speed and automation. There are many ways to get varying levels of accuracy, and most labs will look for a happy medium with a level of consistency that they can accept that provides a level of speed that will provide the throughput they need. We will go into the general components that would be found on these units.

Calibrated glass viscosity tubes – Samples are generally introduced to some sort of glass tube. Glass is used so that the lubricant can be observed while testing is happening. The tubes are shaped so that there is a section for the lubricant to heat up to the proper temperature, and there is also a section for where the testing actually takes place – generally either sensors that can identify when the lubricant is in the correct place, or lines for the tech to start and stop a stopwatch to calculate the viscosity.

Heated Bath - Lab equipment will generally have the viscosity tubes immersed in a fluid bath to get the lubricants to be tested up to a specific temperature. The bath should be circulated, and will have some type of thermometer that can tell when the fluid is at the proper temperature.

Sample Introduction - Samples are introduced usually through some volume of measure to get consistent results across all samples. Whether a pipette or a dropper or some type of automated loader is being used, the end product is supposed to be consistent and produce precise results; so as long as that is achieved the sample introduction is really more or less inconsequential where the end user is concerned.

Whether you have sophisticated timing equipment or a stopwatch, lab equipment is measuring the time it takes for a lubricant, heated to a very specific temperature, to get from point A to point B. Once you have that time, you can calculate the kinematic viscosity based on what the calibration of the tube. This will generally vary greatly from tube to tube within a single testing unit, let alone from one unit to another, so I will not delve into how this calculation actually works.

The problems that arise from this testing method have to do with factors that affect pressure within the tube. Entrained gas such as Ammonia from a refrigeration compressor lubricant can expand during testing, causing a sample to move through the test zone abnormally fast and produce an erroneous result. For this reason, it is critical to make sure the lab knows what type of unit they are dealing with so that appropriate measures can be taken. There is a simple procedure to fix this one particular problem if they know about it.

Another issue comes from having water in the lubricant. Testing performed at 100°C will boil water, causing the same problem as in the entrained gas – the lubricant being tested will flow through the test zone at an abnormal rate, making the results inaccurate. This kind of problem is not something that can be anticipated by the end user – you are sending your samples in to find that kind of thing out – but the sample evaluator should be able to spot that and at least mark the viscosity as inaccurate in your report due to the water present.

On-site Testing Equipment

On-site testing equipment varies a great deal from its laboratory counterpart. The ingenuity of how various companies manage to extract some measure of usable data just astounds me sometimes. I will go a little bit into what to expect from a field viscosity unit, but because of the vast differences from unit to unit, and the vast number of units there are out there, I will only touch on these points briefly. Most of what we need to go into will be how field units differ from lab units, so I'll spend most of the time here on that.

On-site equipment works in a fundamentally different way from most lab units. This is a little more in-depth than is absolutely required, but because of how it affects the results, I really feel it should be touched upon. They both test resistance to flow, but they are testing different aspects of it. Laboratory equipment generally tests directly into cSt by testing the fluids internal friction, or the speed that the molecules will move through each other.

Because of the equipment required to do that, it is just not feasible to have that type of apparatus in the field. Field units' primary design focus is ease of use and portability. Because of this, the apparatus is made very simple by usually having an external tester that can be either wiped off or an internal tester that is easily cleaned. The problem with this is that you are no longer testing the fluid's internal friction – you are testing the fluid's resistance to shear. While they are very similar, they are not the same. These test results will generally end up in a test result called Centipoise or cP – most of the time you will not even see this result. A calculation can be done off of the cP result to get cSt, but it will always have some amount of variation.

The calculation for conversion from cP to cSt is one of the primary drawbacks with a field viscosity tester, but another main drawback is the inability to control temperature. Needing to know what the viscosity is at a specific temperature is a required function of viscosity, but field testers generally have no way to control the fluid temperature during a test. This can be overcome by some degree with knowing the temperature of the lubricant at the time of the test, but it introduces a second calculation by calculating the viscosity change when going from the tested temperature to the temperature you need to know – 40°C or 100°C.

The third drawback comes in the same area of temperature. Because the calculation done to do temperature correction involves the Viscosity Index, if you don't have the exact Viscosity Index of the lubricant that is being tested and you just have a manufacturer's batch result on what the "typical" properties are, there is another possible flaw in your second calculation.

The reason why I have gone more into the drawbacks of field units versus laboratory units is not to make you think your field units are a waste of time. They are an absolutely vital tool that, in most cases, will get you very close to what the laboratory would be providing you, and they do it in real-time versus the lag time you get when sending in samples.

I have gone more into the drawbacks here to educate in why your field result may not be coming back exactly what your lab result is telling you, and to help you narrow down the problems you may be having with your field testing to possibly get a more accurate field result.

Particle Count, a brief review

I would like to again start with the basic concepts you will need for this portion of the session. I'm sure most of you are familiar with an ISO cleanliness code. This is the two or three number code that tells you how clean your lubricant is. The three numbers correspond with an index of the number of particles present at the three particle sizes being looked at.

Just as an example, let's say you have an ISO code of 16/14/11. The 16 is referring to the number of particles equal to or greater than 4 microns. The 14 is referring to the number of particles equal to or greater than 6 microns. The 11 is referring to the number of particles equal to or greater than 14 microns.

You are probably not familiar with the standard applied to the results you see from particle counting, but if you have results from 4,6, and 14 in your ISO code, these are from ISO calibration standard 11171. The standards revolving around particle counting are constantly evolving as newer and more accurate ways of counting particles in fluid are discovered, but currently you should be able to ask what ISO standard is being used and find that 11171 is in place at any modern moderate to high volume laboratory.

Overview

Lubricant particle counting is truly a very small subset of particle counting in general. Every industry that has a cleanliness-critical application is concerned with a particle count, be it a clean room at an Intel processor factory or a water treatment plant needing to check water cleanliness, particle counting is everywhere.

The two units we will be looking at here are the Pore Blockage unit and the Laser Counter unit. They differ significantly in how they work, and so I will be going into how they differ in reporting and benefits versus drawbacks after I give you a general idea of what they are and how they work.

Laser Particle Counters

A laser counter is what is usually employed for particle counting for lubricants, mostly based on its ease of use and relatively short sampling time. They are generally low maintenance, and calibration is fairly straightforward. A laser counter will typically have a sensor, some way to force lubricant through that sensor, and some manner of equipment to read data from the sensor and report it.

Various sensors have differing abilities regarding how much data can be pulled from a single testing round, so some labs will report more information than others, but in general you should get 4, 6, 10, 14, and a few larger sizes possibly up to around 100 microns.

Test results are usually repeated, just because of the variability of particle count results. The typical process is to run the sample 2+ times and then average the results. This not only gives a nice averaged number that is likely to be closer to the true value, but it also allows the technician to monitor the results coming off of the data to see if the equipment may be malfunctioning and thus help improve data quality.

Drawbacks to using a laser counter are numerous. Water will show up in a laser particle counter as a particle, so anything with water contamination will not be able to get a particle count. Air also shows up as a particle, so all samples must be vacuum degassed prior to running a sample which extends the time per sample making it a more costly process, and also introducing the possibility of particulate settling causing a particle count that is inaccurate. Also, the sample must be transparent. Because the counting involves a laser light and a receiver picking up that light, any completely opaque or cloudy (through fine particulate) sample such as diesel engine oil will completely block the light and preclude any possibility of obtaining a particle count.

In spite of the drawbacks, the laser counter is still the most likely particle counting unit you will ever find simply because it is very accurate with little effort when the samples being tested do not have any of the above mentioned issues.

Pore Blockage Particle Counters

A pore blockage particle counter I would suspect is the second most likely particle counting unit from which you would ever receive results. The pore blockage units test particle count based off of the pressure put on a grid of pores at a specific size. The grid fills with particles at a specific size, and as the grid fills, the pressure put on the grid increases, and this pressure increase corresponds directly with the number of particles present on the grid and can thus be translated over to a number of particles present in the volume of oil used for the test. You can generally get different pore sizes on different grids if you are going to be testing fluids dirty enough to saturate a smaller pore grid.

The benefits to using a Pore Blockage unit are many – it is not affected by water, air, or lubricant opacity. Basically it appears to be a counterpoint to the laser particle counter. Unfortunately there are two glaring drawbacks to using this type of unit.

For one, the time for running a sample can be immense. Because you are trying to cram a lubricant through a grid of holes just a few microns in size, this isn't going to happen in a few seconds like is the case with laser counting. This can take up to 20 minutes and more depending on the viscosity of the lubricant, and this kind of sample processing time is generally cost-prohibitive for a laboratory and thus the cost-per-sample is pushed way up and that ends up on your bill.

The second drawback is really the worst one. Because you are getting the particle count off of one particle size, all of the other particle counts are based on extrapolation from that one number. There is a calibration done to make this extrapolation possible, but what it amounts to is a particle count that is only loosely based on what the real particle count is. This is not to say that there is no place for pore blockage units. Without them, particle counting on diesel engine oils would not be possible without significant dilution, nor would particle counting be possible on water/oil emulsions. You just have to keep these drawbacks in mind as they significantly hinder the scope of where you should really consider pore blockage as a useful particle count method in your application.

Conclusion

While this is a very brief overview of viscosity and particle count, hopefully you have gained some of the basics in these tests. This only scratches the surface of the technical information available about viscosity and particle count. If you have any interest in this I highly recommend you start searching on the internet first and then contact your lubricant testing facility and see what kind of information they may have to offer.