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Removing Varnish with Adsorption

6 Steps for Effective Oil Analysis

Particle Monitoring in Gear Oils

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TECHNOLOGY

Adsorption: A Simple and Cost-effective Solution to Remove Varnish

By Justin Stover, C.C. Jensen, Inc.

Varnish has emerged as one of the deadliest of oil contaminants in industry. Just like heat, particle and moisture contamination, varnish acts as a so-called soft contaminant that severely impacts lubrication and machine reliability.

Varnish has been the topic of numerous technical papers and articles. No doubt many who read this article are all too familiar with the damage caused by varnish and the challenges associated with monitoring and controlling this ever-increasing problem.

A major issue is that varnish is known to be smaller than the size ratings of most filters and, therefore, cannot be removed using conventional pore-size related filtration. This article focuses on adsorption - a practical, simple and relatively low-cost solution to varnish removal.

Adsorption is the adhesion of molecules to a solid surface. Adsorptive filtration is the retention of particles to a filter medium by electrostatic forces or by molecular attraction.

For better understanding, it is helpful to address four common myths related to varnish removal.

Myth No. 1

The only technology available to remove varnish is electrostatic separation.

Adsorption media such as cellulose has been used successfully for many decades. World-class companies have used this method as a simple, powerful and effective means to remove varnish.

Myth No. 2

Varnish removal systems directly clean varnish deposits from machine surfaces.

A varnish removal system can remove only soluble and insoluble particles that pass through it. It is the ultra-clean oil circulating through the machine that removes varnish deposits. These deposits are lifted by the solvent action of the oil and then transported via the oil to the filter system for ultimate removal and collection.

Forces Governing Adsorption

Two generic types of adsorption are recognized: physisorption and chemisorption.

Physisorption depends on weak physical attraction of the solid phase (adsorbent filter material) for components in the fluid phase (varnish molecules). It is characterized by the fact that physisorption is: (a) sensitive to temperature, (b) relatively nonspecific among constituents in the fluid phase, (c) relatively fast because there is no significant activation barrier, (d) possibly occurs in multiple layers on the solid surface, and (f) the magnitude of the heat of adsorption is relatively small.

Conversely, chemisorption occurs by chemical bonding via electron transfer. It is characterized by the fact that it is: (a) specific, (b) relatively slow due to the existence of an activation barrier (with associated chemical kinetics), (c) exhibits monolayer formation on the solid surface, and (d) the magnitude of the heat of adsorption is relatively large.

Though certain aspects of lubricant filtration imply that the uptake of varnish particles might involve chemisorption, it is more likely that physisorption governs their uptake. Thus, the remainder of this section is devoted mostly to that topic.

The forces of physisorption fall into two main categories: van der Waals (or dispersion) forces and electrostatic forces.

Van der Waals forces are weak molecule-to-molecule forces that cause a small particle to adhere to a surface, for example, as dust sticks to eye glasses. Electrostatic forces can be subdivided into polarization forces, field-dipole interactions, and field gradient-quadrupole interactions. These forces occur only if the surface is polar and are represented by a Coulombic potential function.

The last type of electrostatic effect is called hydrogen bonding. It is a specific form of electronic interaction which is important for polar, partially oxidized molecules, such as varnishes and surfaces, such as cellulose. On account of the generic chemical structures for varnish identified earlier, it is likely that hydrogen bonding is important for removing varnishes from lubricants.

In summary, adsorption of varnishes from oil likely occurs mostly by physisorption instead of chemisorption. The phenomena that contribute to physisorption are van der Waals (or dispersion) forces and electrostatic forces. Of these, van der Waals forces depend on the polarizability of the varnish molecules.

Electrostatic forces that are important for varnish in contact with cellulose include polarization forces, field-dipole interactions, and especially hydrogen bonding. While these provide a means for understanding the interactions and might someday be a basis for computer simulations, today we are limited to using our understanding merely as a basis for choosing materials and subsequently performing empirical analysis.

Myth No. 3

The size of a varnish removal system does not matter.

When it comes to varnish removal, size truly does matter. Each varnish molecule occupies a certain amount of surface area. Thus, a removal system should have a high specific surface area to accommodate the varnish that has been removed.

Size is also a factor in terms of pump flow. The rated gpm of the varnish removal system plays a large role in the removal speed of varnish deposits. A higher turnover rate of oil in the machine will enable the purification process to stay ahead of varnish production rate. The cleaning process of varnish deposits is likewise accelerated by a higher flow rate, allowing more oil solvency to take effect.

Myth No. 4

Varnish is not a threat to all oils.

All oils are susceptible to varnish because oxidation occurs in all systems.

Adsorption

Adsorption is the selective physical and/or chemical binding of atoms, molecules or particles to a surface, called the adsorbent, such as activated carbon and silica gel. Do not confuse adsorption with absorption. Absorption is not selective and takes material into the absorbent material, as a sponge does with water.

A major distinction between classical adsorption and filtration systems, as a process element, is that the performance of adsorbers typically depends strongly on temperature, flow rate, concentration and other operating conditions, while filters are less sensitive to such conditions.

It is clear how employing adsorption as a capture mechanism in combination with filtration could be a promising way to remove varnish particles. The key is finding a filter medium that also functions as an effective adsorbent.

Therefore, it is necessary to understand the fundamental physical and/or chemical forces that cause binding of molecules or particles to the adsorbent filter media.

Some high-quality oil filters utilize cellulose which can be used as an adsorbent. It has a high surface area and, due to its chemical nature, the fibers are highly suited to pick up oxygenated organic molecules such as varnish.

Adsorption Compared to Electrostatic Separation

Lubricants and oils that have experienced severe oxidation and heavy varnishing may not be adequately reclaimed or filtered to continue useful service. However in most cases, varnish and other soft contaminants can be removed from the oil and the oil returned to service.

Two common methods of varnish removal are electrostatic separation and adsorption. How does adsorption compare to electrostatic separation?

Electrostatic Separation

Electrostatic separators operate in a low-flow, off-line or kidney-loop installation. They operate on the premise that charged particles precipitate to a collection media or plates of the opposite charge. Disadvantages reported when using electrostatic separators include:

- High purchase cost and operational costs
- Low varnish holding capacity of collection media
- Efficiency drops with the presence of water in the oil (500 ppm or greater)
- Low flow rates
- Complex control systems

Adsorption Kinetics (Movement within the Oil)

In order to adsorb varnish molecules (or particles), they must be brought into contact with the adsorbent surface. That sounds simple, but there are some complications. Most importantly, there is resistance to motion from the oil to the adsorbent surface. The rate of uptake, or the adsorption kinetics, depends on that resistance. In addition, instead of being a single resistance, it is a combination of resistances.

Figure 1. Filter Outset

Figure 2. Filter Exhaust

Figure 3. Overview

To illustrate visually, Figures 1 and 2 show a before and after rendition of a loose bundle of cellulose fibers (pale yellow) in the midst of oil containing varnish particles (gold). Figure 1 shows the contaminated oil approaching the fibers early in the life of the filter. Figure 2 shows the nearly loaded filter still producing clean oil, at some later time, having nearly exhausted the adsorbent. One of the features is that the varnish particles shown are too small to be captured by physical forces such as impaction or sieving, but rather are captured by adsorption, due to the molecular forces mentioned earlier.

What happens inside the fiber can be viewed according to Figures 3 and 4, which show a cross-section of a typical fiber, comprised of dozens or hundreds of cellulose molecules, shown as smaller not-quite-circular sections. The space between those molecules inside the fiber is shown in pink, but it is intended to be open space. To the extent there is binder, it may, of course, penetrate the space, but a skin is shown, along with a fictitious film (blue).

Figure 4. Inside the Filter Media

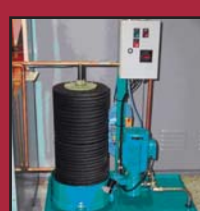

Figure 5. Governor Filter Varnish Removal

Let's consider what happens to the varnish molecules (or particles). First, there is the transport from the oil to the boundary of the adsorbent (for example, a bundle of fibers). This is frequently referred to as film diffusion because the resistance is pictured as a fictitious stagnant film. Second, there is diffusion within the adsorbent (sometimes referred to as macropore diffusion).

This could be viewed as among or between fibers. Finally, there is diffusion from the pore fluid to the adsorption sites at the adsorbent surface (sometimes referred to as micropore diffusion). This could be viewed as among the molecules. All of these depend on geometry, temperature, fluid properties, etc.

Adsorption Systems

Adsorption systems are also installed in an off-line or kidney-loop manner. Unlike electrostatic units, adsorption units can provide a higher range of flow rates, from low flow (<5 gpm) to high flow (>50 gpm). The adsorption media commonly used in off-line filters is a high-density, depth-type cellulose filter. With these filters, it is possible to combine particle, moisture and varnish removal in one system.

However, removing varnish particles requires other forces besides ordinary physical forces employed in particle and moisture removal (impaction, absorption, etc.).

Beyond the Classic Filters

Although classic oil filters are frequently used in many industrial applications, they are limited to removing dust and debris above a certain size, for example, 2 to 20 microns. In contrast, because lubricants contain a variety of contaminants besides dust and debris, it is important for the longevity of equipment that the surfaces remain free of varnish.

To keep exposed metal free from such deposits, varnish and similar contaminants must be removed by filtration that goes beyond the classic filters. Adsorption is one means for accomplishing this goal because it provides a powerful and effective means to remove varnish.

Cellulose is particularly effective in this regard; its high polarity is well-suited to attracting and removing varnish. The adsorption characteristics of cellulose are inherent. Therefore, unlike electrostatic separators, no voltage or control systems are required. Capacity is determined solely by surface area. Just one gram of cellulose has a surface area of approximately 4,000 ft^2. A standard filter cartridge contains 3,600 grams of cellulose, producing a staggering total surface area equal to 300 football fields.

To appreciate the impact of adsorption, one must understand the principles of classical filtration, the characteristics of varnishes and other contaminants and the basic ideas that govern adsorption. These explain how and why cellulose, in particular, is a superior means for removing varnishes from contaminated oil.

Adsorption and filtration are fundamentally different. The former relies on a range of forces that require physical chemistry to understand while the latter typically relies on simple physical forces, and captures particles by impaction or sieving. By combining adsorption and filtration, it is possible to attain high efficiency of varnish removal with a relatively simple, inexpensive and compact device. **POA**

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An Oil System free from Varnish Deposits

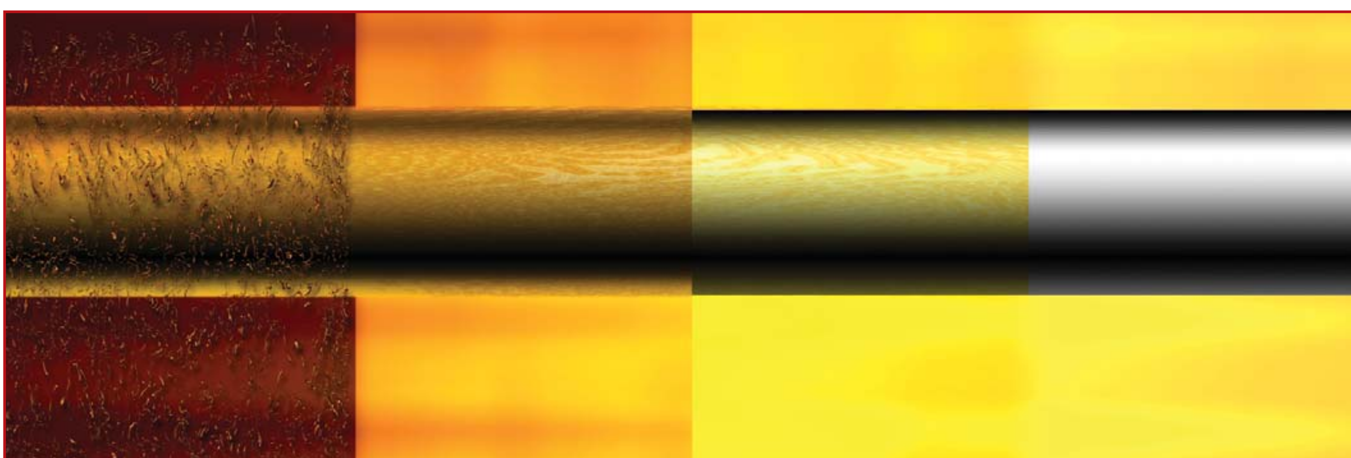
Removal of varnish deposits from metal surfaces

By using CJC™ Off-line Filters, the amount of varnish deposits on metal surfaces will be reduced. It is explained by the adsorption equilibrium behaviour.

There is an equilibrium between the two phases, i.e. the fluid (oil) and varnish on the surfaces. When the oil becomes cleaner, the deposits from the system become unstable because the concentration of oil degradation products in the oil has decreased. This will result in a decrease of the amount of adsorbed substance. In other words, this means that the oil degradation products on the metal surfaces are released. The oil functions as a system cleaner.

CJC™ oil filtration will maintain both oil and system cleanliness

- Longer oil life
- Increased oil performance and lower energy consumption
- Increased productivity
- Less maintenance
- Environmentally friendly



Problem

The oil is contaminated by hard contaminants, water and soft contaminants, which lead to varnish deposits

Solution

Removal of the contaminants by CJC™ Off-line Filters before they will form sludge and varnish deposits

Result

Lower levels of contamination, which will prevent deposit formation. Futhermore the deposits, once formed, will be reduced by using CJC™ filtration

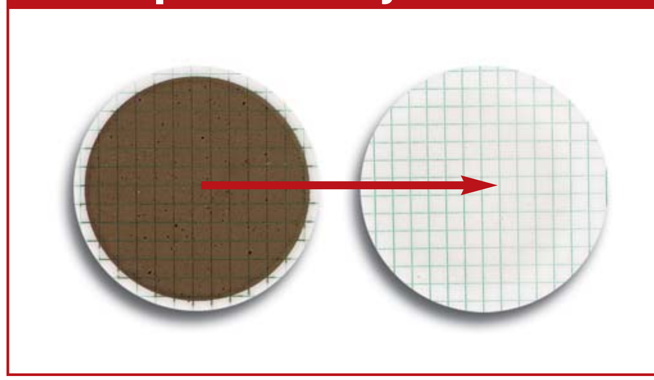
Maintenance

By CJC™ oil filtration you will maintain both oil and system cleanliness

With C.C.JENSEN the Results are Clear...

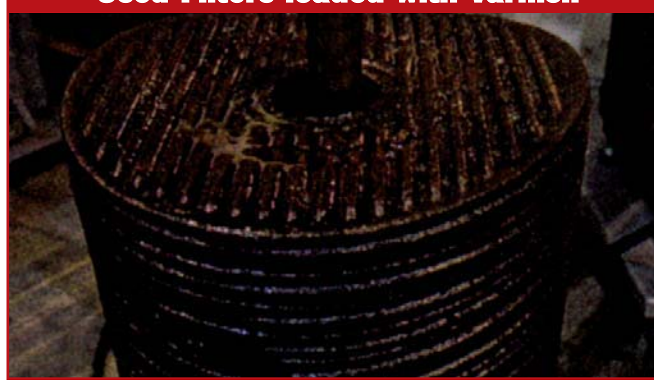
Enhanced Oil Clarity

Improved Oil Analysis Results



Cleaner Components

Used Filters loaded with Varnish



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