Particulate Contamination: How to Quantify Parts Cleanliness

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Introduction
Precision parts need to be thoroughly cleaned before use in critical applications. This statement will not draw many arguments. What will begin discussions, however, is how clean they need to be to achieve their desired performance, and how this cleanliness is defined.

The degree to which a part must be cleaned depends, of course, on its ultimate application and specific intended function. One might consider a part that allows an airplane to fly (continue to fly) to be more critical than a component that allows an automobile to operate. Similarly, a brake component on an automobile could be considered more critical than an engine component. But criticality of function is only one criterion. One must also consider the sensitivity of the part to contaminants. For example, the clearances between moving parts can establish the size of particles that can cause a problem.

Although no one would complain about a part being too clean, the time or cost involved with achieving this cleanliness may be more than is warranted. The goal should be to define the level of cleanliness desired, determine the method to do the cleaning, and measure if it is achieved.

Intelligent selection of a cleaning process requires quantifying the cleanliness achieved with each method. Traditionally, a cleaned part is flushed with a liquid that’s subsequently collected and run through a very fine filter patch. The filter is dried and examined through a microscope or weighed.

Level of Cleanliness
Microscopic examination to determine the size and quantity of particles is time-consuming and tedious. Additionally, the subjective results are very much operator-dependent. The gravimetric process provides a measurement of contaminant by the weight of material flushed from the component’s surfaces. The major disadvantage of this method is that the data are simply a gross measurement of the contaminant’s weight. For example, a gravimetric analysis showing 0.2 mg of contaminant could be made up primarily of particles in the 50 to 100 micron range with a total count of 1500 particles. Alternatively, it could be comprised of particles smaller than 25 microns, but present in much greater quantity.

Determining actual size and quantity is necessary to evaluate the contaminant’s effects on the component. A small number of particles in the 50 to 100 micron range may have a much more serious impact on the component than a much larger number of particles in the 2 to 25 micron range.
Depending on the application, particle sizes of concern can be established from dimensional relationships. For example, the clearances of moving parts can help define the maximum particle sizes that can be tolerated.

The size and count quantifying ability offered by microscopy and optical particle counters (OPCs) enables manufacturing personnel to develop a better analysis of their cleaning processes. OPCs allow quick, repeatable measurements of particulate contamination by size and quantity. Automatic particle counting can be used to improve process efficiency. Also, decision making for quality control is made easier. In some cases, a contaminant’s size helps quality control personnel to identify its source, saving precious time and money.

**Particle Counter Basics**

OPCs count and size particles by measuring the signal produced on a photodetector when a particle interacts with a beam of light. Two major techniques are employed: light extinction and light scattering.

Light extinction (or light blocking) devices use a light source, typically a laser diode, to provide a continuous beam of light through a small flow channel onto a photo diode (see Figure 1). As a particle passes through the sensing zone, it blocks some of the light. The change in level of light intensity on the photo diode creates an electrical pulse proportional to the size of the particle. This technology provides very accurate measurement down to about 1 micron.

Light-scattering sensors measure the light “scattered” by a particle as it passes through the light beam. In this method, no light arrives at the photodetector when no particle is present. This technology can detect particles down to 0.1 micron and smaller. Although light scattering also can detect particles greater than 1 micron, the upper limit is typically 25 microns. The pulses are fed into a microprocessor where they are counted and sorted according to size. The result is a report of number of particles by size.

Some sensors available combine light scattering with light extinction to extend the measurement range with one sensor. The limitation with both approaches, however, is that particles are sized as equivalent spheres. This one-dimensionality results in missing detail of the particle shape observable with the microscope. But OPCs more than compensate with efficiency - extremely rapid evaluation with a very high degree of accuracy.

**Components in the System**

Every particle counting system is composed of three parts: the sensor, the counter, and the sampler. The sensor is the component where the particles interact with the light source. It contains the laser diode, the flow channel, and the collection optics.

The counter is the component through which the user specifies what sizes of particles to count, and receives particle count data. The counter also contains the electronics that process the signal from the sensor, converting the voltage pulse into its corresponding
size. Modern counters incorporate a microprocessor that significantly improves ease of use as well as the information that can be obtained.

The sampler has only one mandatory job: to deliver the particles to the sensor at a constant, known flow rate. It may do other tasks, also, such as measuring the sample volume or providing a vacuum to degas the sample. Because the essential job of the sampler is so simple, its design can vary dramatically - as simple as a valve downstream of the sensor in an on-line application or more complicated, such as a recirculating system.

**Methods of Monitoring**

How manufacturing plants evaluate product contamination is an important part of the cleaning process. Such evaluation includes several steps, including extracting contamination from the products, examining the contaminant profile, determining the root causes, and correcting them.

For proper evaluation, parts are cleaned thoroughly to remove all contaminants. Popular methods include ultrasonically loosening the contaminants and flushing of parts. The approach chosen is highly application dependent.

The most common use for OPCs in parts cleaning applications has been to analyze the final solvent wash. Either it or a separate wash to remove particles is collected in a sample bottle and the particles are counted in a batch sampler. This method allows one particle counter to be used to monitor many different cleaning processes.

To improve the throughput of a cleaning operation, the OPC can be plumbed directly into the apparatus. With this configuration, the cleanliness of the cleaning fluid can be monitored continuously, and the user gets immediate information on how the cleaning is proceeding. The cleaning can continue until the parts are adequately cleaned.

An intermediate step between batch and in-line monitoring has been made available with the development of truly portable liquid particle counters. Users may take the device from one system or cleaning stand to the next, plug it into a sample port, and obtain immediate information on the cleanliness of each station at any time during a cleaning process.

**Summary**

With customer demands for quality ever on the rise, it’s becoming more critical to manufacture products that are free of contamination. But this objective requires addressing issues on all fronts - design of the product, production lines, process controls, etc.

While particle counting technology is more than 30 years old, manufacturing is just now exploring ways to better utilize the information that this equipment can provide. Much of the current increase in particle counter usage is attributable to the switch to alternative fluids being used for component flushing now that CFCs are soon to be phased out completely. Will the new agent clean as well as CFCs? In the search for answers,
cleanliness quantification is of major concern, and reliance on particle counters as a quality audit tool will continue to grow.

Additionally, particle counters are increasingly being used to monitor the cleaning process as well as to audit the final result. Counters can be connected to a system to rinse parts until a certain particulate level is achieved. The rinse fluid itself must be clean enough to flush the parts. Customers can keep a record of particle counts for production records and required maintenance.

Particle counter usage will increase as quality control is pushed out of the manufacturing laboratories and onto the production floor. Processes will be monitored using both on-line and batch sampling, and audited at a more frequent rate.

Quality control of the product and processes will continue to be the area manufacturers strive to improve. Why? Because their success in these areas typically contributes heavily to the financial bottom line with fewer warranty claims and premature component failures during final tests prior to shipment. Particle counters can provide a tool that can be instrumental in the effort to improve quality.
LIGHT EXTINCTION SENSORS

Diagram: Particle Sensing Cell with Laser Diode, Imaging Optics, Collection Optics, and Photo Diode.