Faster, Automatic Identification of Particle Contamination

Industries such as automotive, electronics, and medical devices are particularly sensitive to the performance of precision-manufactured parts. When parts fail, sometimes due to particulate contamination that occurs in the manufacturing process, incomplete coatings or engine damage can occur.

The ability to identify particle contaminants and their origins can be an advantage in manufacturing operations. In automobile production, for example, contaminants range from metal shavings to abrasive residues to small fibers. As engine tolerances tighten, particles that impact performance have gotten smaller. Residue can remain throughout the manufacturing process, causing issues when engines are finally tested.

Traditional methods of monitoring surface cleanliness such as gravimetric analysis can calculate contaminant total bulk weight, but do not produce individual particle data. As a result, components may pass gravimetric testing, yet fail to function due to individual “killer” particles that can cause issues. Some manufacturers see dangerous abrasive contaminants, such as aluminum oxide, that are just 2 μm, which are not detected via traditional gravimetric testing yet cause engines failure.

**Traditional methods**

Many options for monitoring particles on automotive component surfaces are available. It is important to thoroughly understand the features and benefits of each approach.

**Bulk/gravimetric testing** — Bulk/gravimetric measurements have long been used to quantify foreign material presence by measuring filter weight before and after part flushing. The part or assembly is typically flushed and residue is collected on a pre-weighed filter. The loaded filter is dried and weighed, indicating the total mass of collected debris. This method only provides a gross or an undifferentiated measure of the amount of material present. The weight or volume of filtered materials sheds no light on particle size, shape, or composition, which is necessary to improve design or control processes.

**Particle counters** — Particle flow-counters disperse particles in fluid. Particles are then passed through a flow cell where they are detected by an optical or laser sensor. Such devices can accurately count thousands of particles per second, and often provide a graph of particle size distributions. However, most counters assume particles are perfectly round. As a result, particle counter manufacturers report out an equivalent diameter using various algorithms, making comparisons between particle size reports from different manufacturers difficult and/or inconclusive. Particle counters also may experience false positives, which typically result from air entrapment or water in the oil. While these units are useful for monitoring trends of established particle populations, they are less valuable for understanding unknown or changing particle populations (clear signs of changes in surface contamination on a part or component).
Optical microscopes — Individual particles are observed and their size is estimated. This manual particle sizing is simple to perform, but is tedious and time-consuming. In recent years, optical microscopes evolved to include cameras and motorized stages. By interfacing both to a computer, automating the particle detection/sizing process is possible. It is practical to routinely measure distributions consisting of thousands of particles and sort them by size and shape. However, the chemical composition of the particles remains unknown.

**Alternative method**

Determining the elemental composition of these microscopic particles helps define the contaminant’s origin and provides concrete information that allows manufacturers to conduct quality control analyses to improve production processes. When a product needs to be verified as suitably free of a specific kind or class of particulate contaminant, such as a toxic or abrasive material, other methods can waste time analyzing benign materials in the sample. Integrated microscopy allows for rapid search of large areas in a sample, targeting problem particles while disregarding empty space.

Scanning electron microscopy combined with energy-dispersive x-ray spectroscopy (SEM/EDX) provides efficient, accurate microanalysis that identifies contaminant's origins. An SEM image of a particle lodged inside a fuel injector is shown, indicating the application of these techniques.
tifies size, shape, and chemical composition of particles. Traditionally, SEM/EDX required personnel to manage the instrument or interpret data. One alternative, the CleanCHK Analyzer from FEI, Hillsboro, Ore., requires little or no expertise to more effectively monitor particle cleanliness by identifying the source of even the smallest particle. The device monitors surface cleanliness by automatically detecting and counting particles, and analyzes their size, shape, and composition within minutes.

Designed for use on the production line floor, the system can identify particles as small as 0.5 µm so that the source of contaminants can be determined and problems can be fixed right away. The instrument allows automated sample setup, analysis, and instrument calibration and provides accurate information on particle size, shape, and chemistry. Classifications can be selected and automatically obtained based on the measured parameters.

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Case study

As the automotive industry has become increasingly sensitive to part cleanliness, implementing integrated, automated, and rapid monitoring at the production level in plants helps improve part quality. One client maintains that its field failure rate (failure within the first 10,000 miles) decreased by 70% while using the CleanCHK Analyzer.

Engineers at the plant developed a study focused on understanding the levels and sources of contamination present in their manufacturing process. Within a fuel injection system, the tight tolerances between moving parts and the small dimensions of a new fuel injection nozzle led engineers to conclude that quantity, size, and shape were all critical factors in understanding their processes. A steel shaving was found to be considerably more detrimental to components than a dust particle of similar dimensions. Elemental composition of the particulate was determined to be a key factor in developing new cleanliness standards.

A cleanliness monitoring process was put in place using the CleanCHK analyzer. The system provides the means to measure performance against cleanliness standards. The process began by collecting samples using a 47-mm-diameter membrane filter with pore sizes between 0.3-20 μm. To ensure a representative sample was collected, cleaning fluid from each part was passed through the filter using vacuum filtration. Filters were then placed directly in the system using a 5-filter sample holder.

The CleanCHK reporter allowed easy management of produced data. Reporting was based on preset internal standards and presented in predetermined templates, which ensures reproducibility from user to user as well as filter to filter. Component specifications in this manufacturing plant are expressed today in the following format: Particles present should (1) have a value less then X mg/surface area, (2) no particle larger than X may be present, and (3) no more than X particles may be present with sizes between X μm and X μm. Compositional analysis for each particle was monitored based on size and shape in relation to a particular chemistry. Compositional information allowed for pinpointing issues even faster. This helps the manufacturer reduce field failure rates by 75%.

For more information: Susan Benes is Product Marketing Manager for FEI Co., 5350 NE Dawson Creek Dr., Hillsboro, OR 97124, 503/726-7500, susan.benes@fei.com, www.fei.com.

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