A New Tool for Contamination Analysis

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Michael Meltzer
Hugh Gregg

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Lawrence Livermore National Laboratory
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A New Tool for Contamination Analysis

Michael Meltzer and Hugh Gregg
Lawrence Livermore National Laboratory
PO Box 808, L-626
Livermore, CA 94551
(510) 424-6923
meltzerl@llnl.gov

Abstract: The Contamination Analysis Unit (CAU) is a sensing system that facilitates a new approach to industrial cleaning. Through use of portable mass spectrometry and various desorption techniques, the CAU provides in-process, near-real-time measurement of surface cleanliness levels. It can be of help in significantly reducing hazardous waste generation and toxic air emissions from manufacturing operations.

1 Background

Most industrial activities require cleaning of both parts and equipment. These activities take time, cost money, and generate waste. Hazardous waste, air emissions, potential worker exposures, liabilities of waste management, transport and disposal—all are factors adding to a company's cost of doing business.

It is surprising how little "cleaning verification" has changed in the last century. In an age that can produce a palm-top computer, the cleanliness of a high tech part, such as an airplane wing, is still determined by such dated methods as the "waterbreak test," in which water sheeting evenly off a part is proof that the part is clean. This method is common in many industries, even though serious contamination problems can be masked by the presence of surfactants in the water, which allow even dirty water to sheet off as if the part were clean.

The fact is that most manufacturing plants do not know how contaminated is each part in its assembly line. Shop foremen rely on procedures shown to clean parts generally well rather than on real-time knowledge of just what's happening in their cleaning tanks.

This lack of real-time knowledge can be dangerous. It can lead to rejected parts when conditions change in a cleaning
bath and are not immediately detected. Rejected parts must be reworked or discarded, and both actions cost the company money in wasted time and materials.

Until recently, there were only a few ways to determine accurately the cleanliness of a part in process and when a part could move to the next manufacturing step. So overcleaning has become the rule. The thinking goes that, if parts are cleaned and cleaned far beyond what most of them need, fewer will be rejected.

Unfortunately, overcleaning leads to another set of problems—additional waste. Using three cleaning baths when two would do generates unnecessary solvent wastes, extra air emissions, and lower-than-optimal productivity. Overcleaning is common in such operations as electroplating, printed circuit board manufacture, and aerospace and automotive parts manufacturing. In many shops, cleaning processes generate the majority of the waste volume.

Monitoring contamination levels on parts during cleaning operations makes such processes more efficient and provides useful feedback for reducing waste generation and air emissions caused by overcleaning, or undercleaning and subsequent rework of the parts. Such real-time process controls could reduce reject rates, raise productivity, and reduce waste management expenses in a variety of high- and low-tech processes.

2 Objective of Study and Results

In response to this need, Lawrence Livermore National Laboratory has developed a sensor system that provides real-time cleaning verification feedback in an industrial production-line environment. The sensor system, termed a "Contamination Analysis Unit," or CAU, is robust enough to be used in a range of industrial applications, both in the private sector as well as in U.S. Department of Energy operations. The CAU is portable so that it can quickly be moved from one part of an assembly line to another. The sensor generates highly precise data and also identifies the types of contamination present. It can distinguish between different hydrocarbon species and detect other common contaminants, such as silicone oils. Finally, the sensor components are inexpensive; the CAU will soon be affordable to small-sized shops as well as to larger plants.

The CAU uses off-the-shelf mass spectrometry technology as well as a probe designed to interface with parts surfaces.
and desorb trace amounts of contamination from the surface, using a combination of vacuum (as low as $10^{-7}$ atmospheres) plus surface heating (up to 225 degrees Celsius). The CAU contains data processing capabilities and a contaminant library for identifying the amounts and types of surface contamination, and its analysis reads out in standard metrics, such as micrograms of contamination per square centimeter of part surface.

The following table depicts how the key features of the CAU compare to existing products or technologies:

<table>
<thead>
<tr>
<th>Table 1. Comparison of CAU with Other Technologies</th>
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<tbody>
<tr>
<td>Technology:</td>
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<tr>
<td>CAU</td>
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<tr>
<td>------</td>
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<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td><strong>Feedback time</strong> (including sample preparation)</td>
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<tr>
<td><strong>Able to analyze chemical compositions?</strong></td>
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<tr>
<td><strong>Portable?</strong></td>
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<tr>
<td><strong>Type of contamination detected</strong></td>
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<tr>
<td><strong>Acceptable substrate composition</strong></td>
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<tr>
<td><strong>Comments</strong></td>
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</tbody>
</table>
a FTIR is Fourier Transform Infrared Spectroscopy

The CAU's big pluses are that it is both a highly portable and extremely sensitive instrument. Waterbreak tests and similar technologies can also be applied in situ, but they do not provide the accuracy and quantitative determination of contamination levels that the CAU does.

Precise measurements of cleanliness levels can be made in the laboratory, but turnaround times to get this data are typically hours or days. The CAU returns highly precise data in one minute.

The MESERAN analyzer, a commercially available instrument, can also return precise data quickly, but it requires that contaminants be doped with a radioactive tracer before being applied to the surface. In industrial settings, contaminants often cannot be specially "prepared." The CAU requires no such doping of the contaminants.

Fabrication of the CAU currently costs considerably less than Fourier Transform Infrared (FTIR) Spectroscopy equipment and an order of magnitude less than laboratory-based technologies, such as ESCA and Auger analysis equipment.

Future miniaturization of the CAU's interface with parts surfaces will allow the equipment's sensors to be lightweight enough to be held in one hand (the sensor is currently 17 pounds), which will increase its portability. The miniaturization is also expected to drastically reduce the cost of the unit.

3 Conclusion

In summary, industrial cleaning of parts and equipment is a widespread manufacturing operation that, in many plants, needs modernization, increased efficiency, and reduced impact on the environment. Modern sensor and analysis techniques, such as the CAU described above, provide the real-time feedback on the performance of a cleaning operation that is vital for process optimization. The Contamination Analysis Technology will allow cleaning times to be shorter, unnecessary operations to be eliminated, and reject rates to be reduced. It will also cut down on both hazardous waste generation and air emissions that originate from both undercleaned, and overcleaned parts. Optimizing industrial cleaning operations is a "win-win" strategy that reduces
manufacturing costs, increases product quality, and helps protect both worker health and the surrounding environment.