Demystifying Large Particle Analysis

STLE Alberta Section Meeting
October 16, 2017

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EQUIPMENT RELIABILITY SERVICES

What is Large Particle Analysis?

How “Large” is Large?

- In traditional used oil analysis, particles larger than about 20 microns in size may be considered “large”
- The human eye can only resolve particles about 40 microns in size up close
- As such, these are particles that still will likely go undetected to the naked eye, but may also go undetected by certain analytical techniques targeted at even smaller particles

Why perform Large Particle Analysis?

- Certain tests can augment and further explain the test results found in traditional oil analysis
- However, these tests are often poorly understood, and lose some of their effectiveness

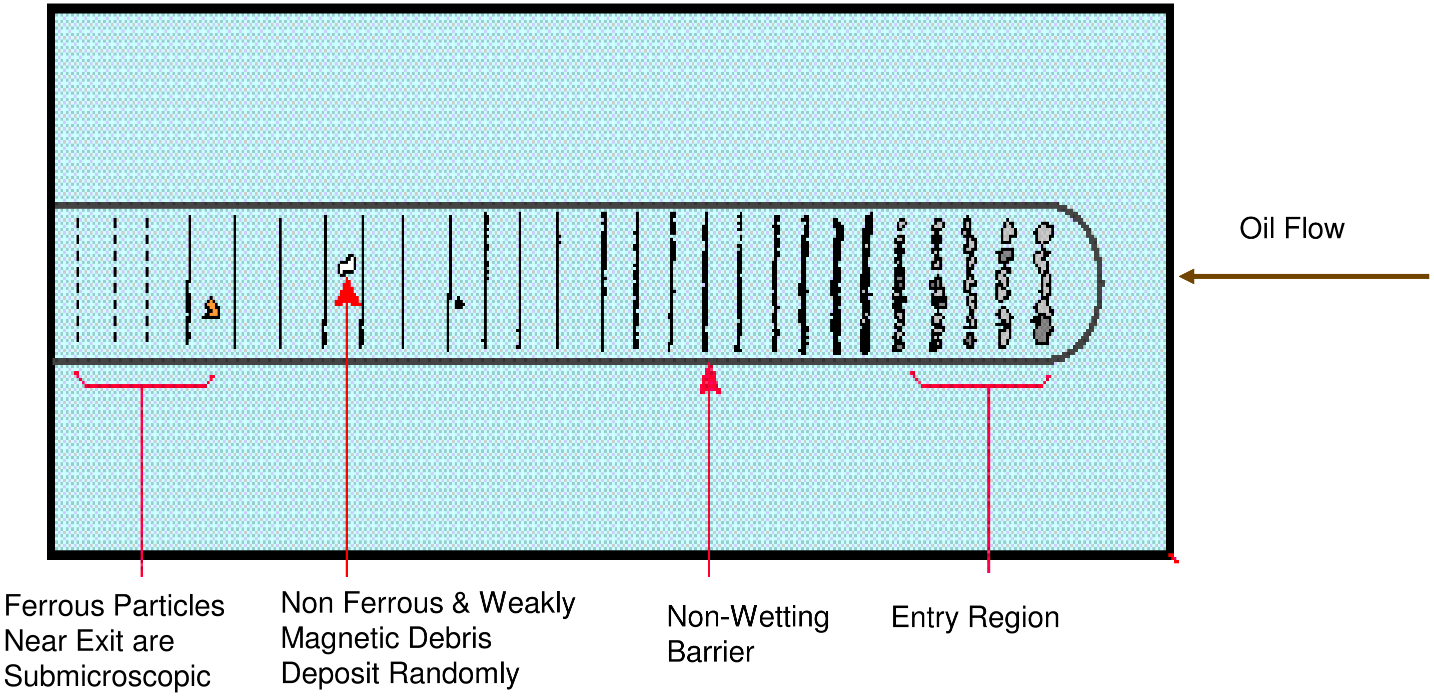
Tonight's Presentation

- We will examine some common analytical tools for assessing large particles
    - Analytical Ferrography
    - Xray Fluorescence Spectroscopy
    - Scanning Electron Microscopy

Analytical Ferrography

- A technique developed in the 1970s to monitor abnormal wear on US military equipment
- Large particles are deposited on a glass substrate

Analytical Ferrography



Analytical Ferrography

The prepared slide is then analyzed using a bichromatic microscope equipped with a camera.

Analytical Ferrography

Key Points:

1. Particles are separated based on size, and whether or not they are ferromagnetic
2. Ferrography looks for *WHAT* is wearing, as well as *HOW* it is wearing (normal vs. abnormal wear modes)
3. A ferrographic report will typically consist of an overall appraisal of the sample, including photos. The data the analyst provides can help the reliability professional determine the root cause of any abnormal wear

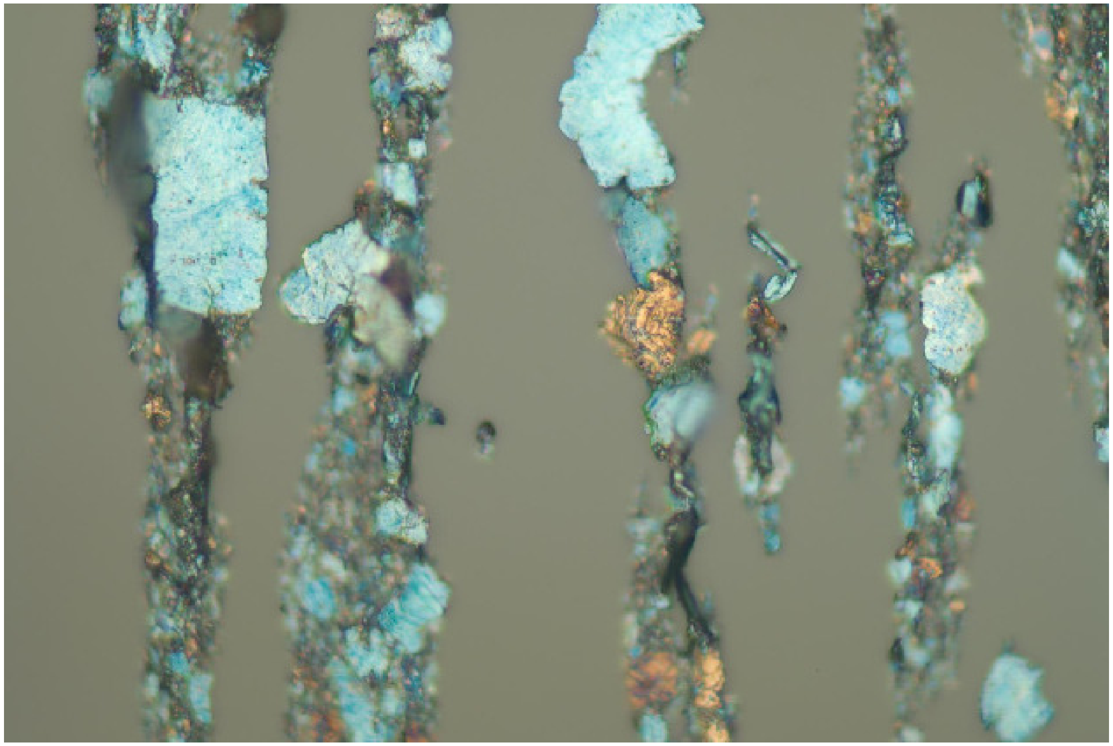
Analytical Ferrography

Particles can be grouped into three broad categories

- Ferrous Debris (steel of various alloys, black metal oxides, rust)
- Non-Ferrous Metallic Debris (Copper, Aluminum, Babbitt material, Chome)
- Contaminants (Dirt, dust, sand, airborne debris, process material, organic debris, fibers, etc)

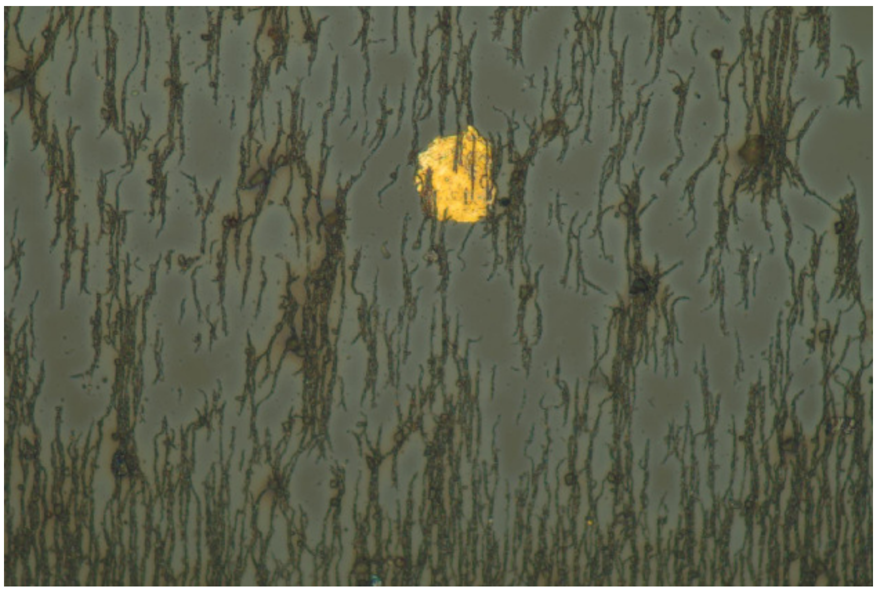
Analytical Ferrography

Ferrous Debris

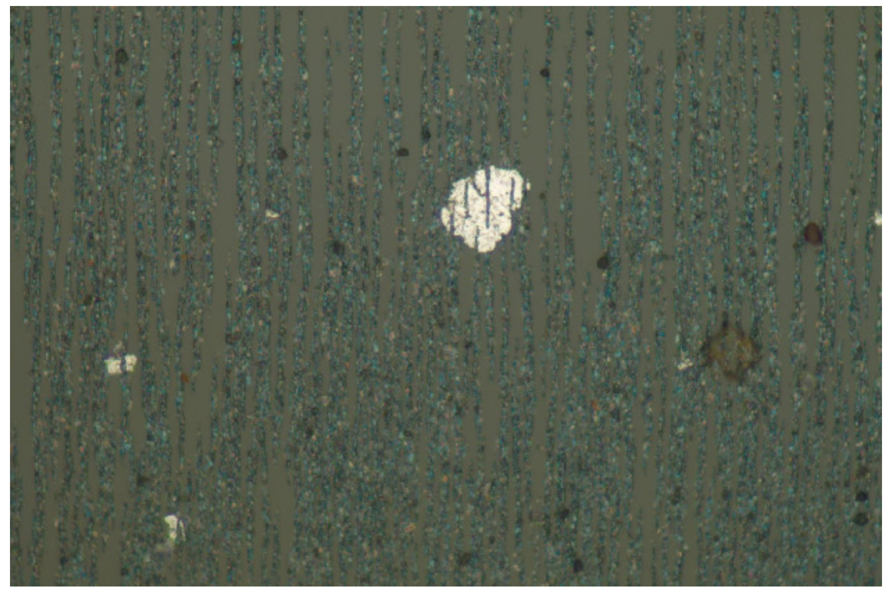


Analytical Ferrography

Non-Ferrous Metallic Debris



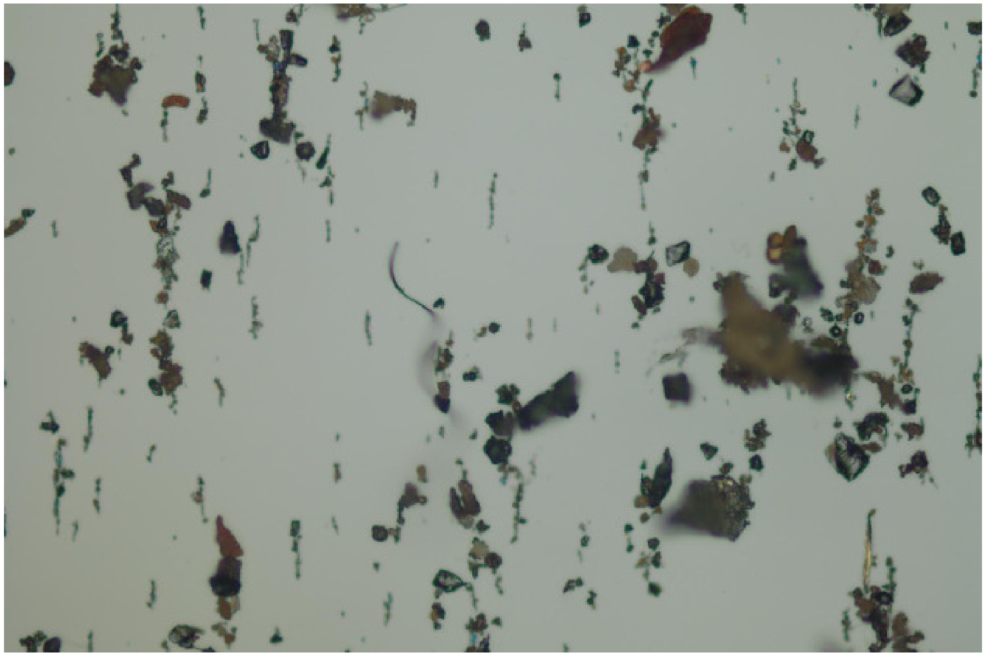
Copper/Copper Alloy



White Non-ferrous metal (Aluminum)

Analytical Ferrography

Contaminants



Analytical Ferrography

Ferrous Debris and Non-Ferrous Metallic Debris can be further classified based on the *Wear Modes* of the particles that are observed.

Analytical Ferrography

Abnormal Wear Modes:

- Sliding Wear (Laminar wear, rubbing wear, Severe sliding wear, some Gear Wear particles)
- Fatigue Wear (Chunks, Adhesive Wear, Spalling, some Gear Wear particles)
- Cutting Wear (Two-Body or Three-Body Abrasive Wear)

Analytical Ferrography

The Component is Critical

- Different Component types generate different types and quantities of wear. It is up to the analyst to determine if the picture they are seeing is acceptable for a given component type.

Analytical Ferrography

How do I interpret the results?

- The value of the Ferrographic analysis can be minimized if the results are not properly understood
- A four-step process will help you get the most out of your report

Analytical Ferrography

Step 1. Note the overall assessment that the analyst has given to your component. (RATE)

- Different labs will have different ranking schemes, but an overall appraisal of the ferrogram will be provided
- Ex) Acceptable, Marginal, Reportable, Unacceptable, Severe

Analytical Ferrography

Step 2. If the ferrogram is flagged as being abnormal, read the comments and look at the photomicrographs to determine what is causing the concern. (READ)

- Is it a certain wear mode in the steel wear? Or perhaps a high concentration of a certain type of particle? Or are the contaminants revealing something else?

Analytical Ferrography

Step 3. Couple the Ferrography report with other data to enhance your understanding of the big picture. (RATIONALIZE)

- Compare the data to the rest of your oil analysis report. Are high levels of wear metals reported, that indicate a condition of accelerating wear? Use the trend of past samples to help you.
- Is there Vibration or Themographic data available? Do any abnormal changes in these results correspond with the increase in abnormal wear seen in Ferrogram?

Analytical Ferrography

Step 4. Using all the data at your disposal, try to source the abnormalities to their source, and proceed with appropriate maintanance. (RESOLVE)

- Use a wear metals chart and OEM resources to source observed metallic wear to certain machine parts
- Potential resolutions will be different based on the abnormalities found

Analytical Ferrography

The "Four R's" of Ferrography Interpretation

RATE, READ, RATIONALIZE, RESOLVE

Analytical Ferrography

In summary…

- Advantages
    - Very powerful analytical tool. Can detect particles that may go unnoticed in other analyses. Provides a description of both the "What" and the "How" of component wear. Can be used to source the root cause of abnormal component wear.
- Challenges
    - Labour intensive test. Requires a skilled analyst. Cost is higher than other routine techniques. Wear particles are qualitatively ranked, but to get an actual ppm quantity of the large particles observed, another technique is needed.

Xray Fluorescence Spectroscopy

Xray Fluorescence Spectroscopy

- XRF is used to measure the quantities (concentrations) of various chemical elements (wear particles, contaminants, and additives)
- Unlike ICP-AES, there is no size limitation restricting what can be observed

Xray Fluorescence Spectroscopy

- ICP-AES can only detect particles up to about 5-8 microns in size. Anything larger goes undetected.
- XRF Data can be compared against routine oil analysis results to check for the presence of large particles

Xray Fluorescence Spectroscopy

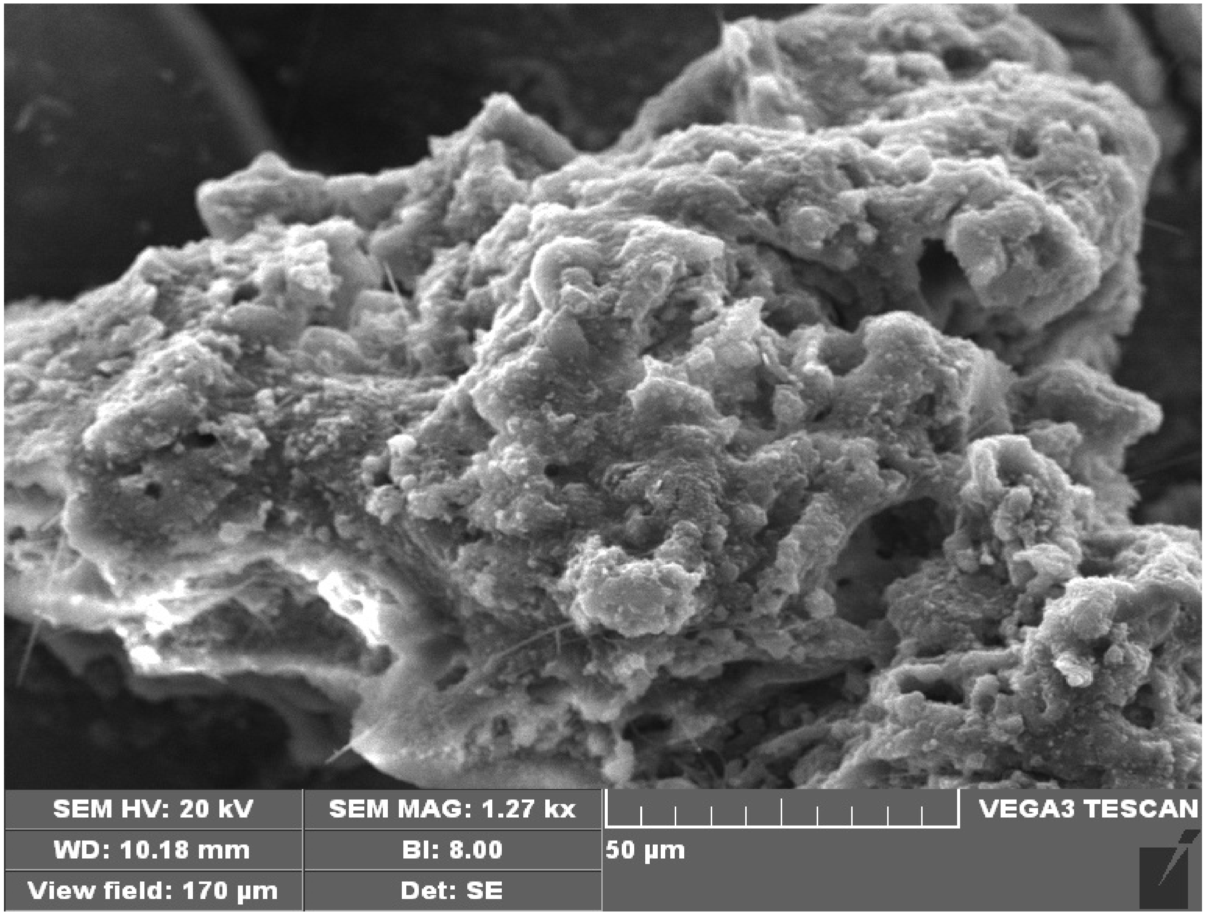
In summary…

- Advantages
  - Can quantify amounts of wear particles, additive elements, and contaminants without a size limitation.
  - Results can be compared to ICP-AES data to get a picture of how much Large Particle Wear is occurring.
- Challenges
  - Cost is higher than other routine techniques. Not practical to perform on every oil sample. No indication of *how* a component is wearing (ie, wear modes).

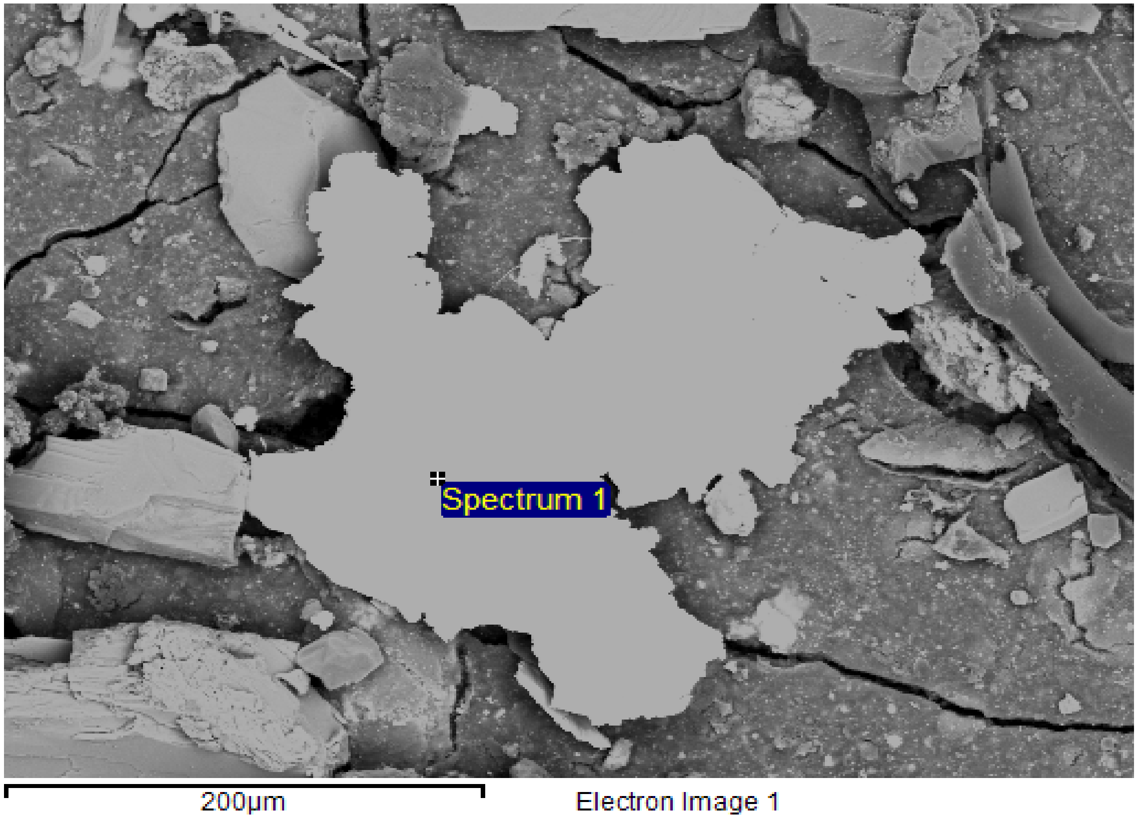
Scanning Electron Microscopy

- Technique uses a highly focussed electron beam to image particles at sub-micron resolutions
- Can be coupled with an XRF detector to determine the composition of a single particle
- Useful for characterization of a specific particle, rather than an aggregate result of what elements are present

Scanning Electron Microscopy



Scanning Electron Microscopy



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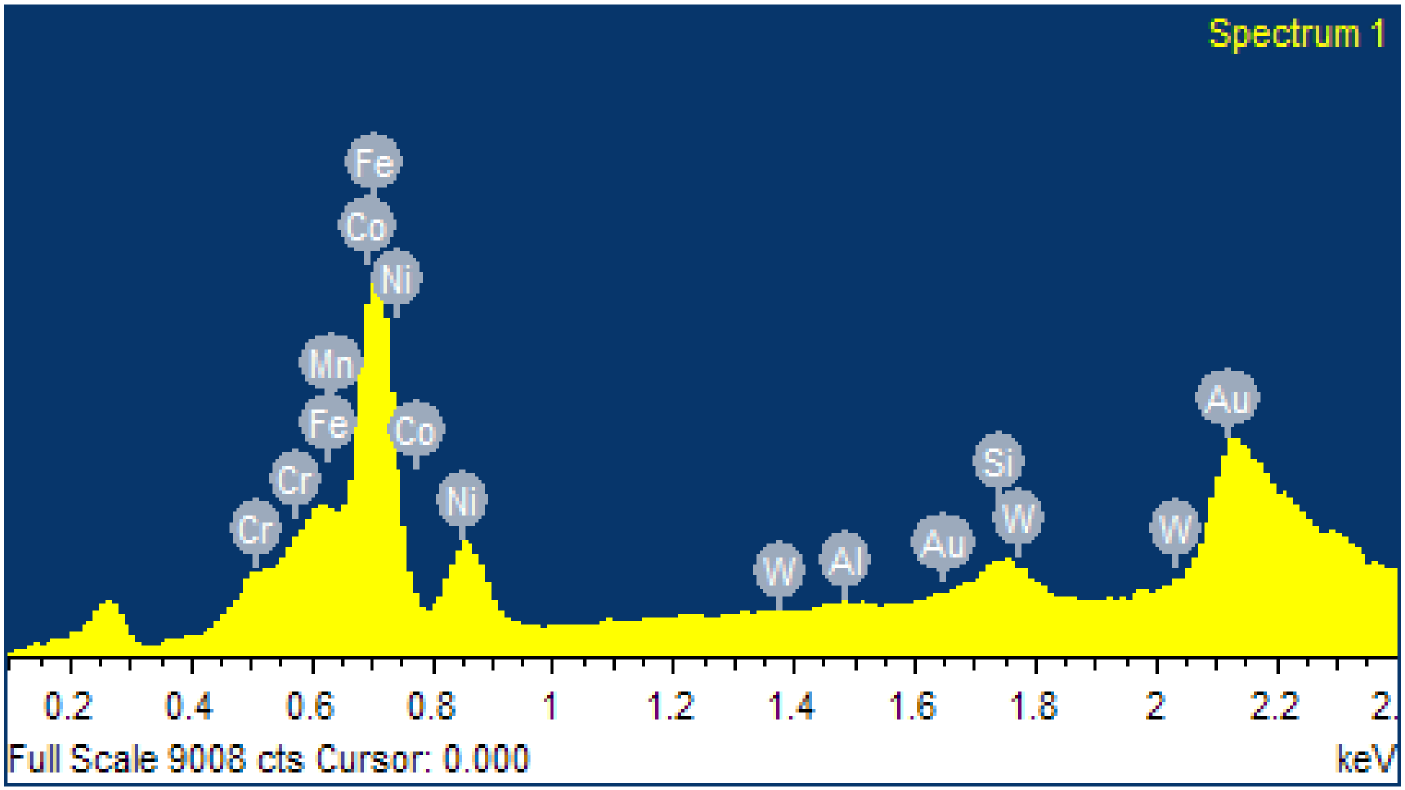
Scanning Electron Microscopy



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Scanning Electron Microscopy

Element	Atomic % Composition
Aluminum	0.36
Silicon	1.48
Chromium	19.18
Manganese	1.93
Iron	67
Cobalt	0
Nickel	10.05
Tungsten	0

Scanning Electron Microscopy

In summary…

- Advantages
  - Combines the best aspects of Analytical Ferrography and XRF to show images of wear particles, illustrating their wear modes, as well as quantitative data about what they are composed of
  - Very powerful tool for determining the identity and origin of a specific wear particle
- Challenges
  - Cost is much higher than other routine techniques. Requires specialized equipment not often available in routine oil analysis labs. In the focus on specific particles, the "big picture" of the component wear may be obscured.

Bringing it all together…

" Knowledge becomes power only when we put it into practice."

- Authour Unknown

Bringing it all together...

- Ferrography, XRF, and SEM all have the power to detect and characterize large particles found in a used oil sample, and help determine their root source
- As they are expensive techniques, their usage can be implemented on an interval or targeted/triggered basis

Bringing it all together…

- The more skilled an end user is in interpreting these results, the more value they can get out of them.
- When in doubt, never be afraid to ask your lab for help!