White Paper

Spectro Scientific / AMETEK

FieldLab 58C

A mobile oil analysis tool to detect abnormal wear and lubrication issues to avoid unplanned repairs

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The new FieldLab 58C is the latest generation of a very innovative portable oil analysis system first introduced in 2012. Unique features of the system include the ability to measure lubricating fluid viscosity, fluid chemistry and abnormal wear debris in a few minutes, and report results. The wear debris approach is a patented approach, developed for addressing the need to detect abnormal (>4 micron) wear particles and determine their elemental makeup.

Figure 1: FieldLab 58C Portable Fluid Analysis System

It is commonly understood that spectrometric oil analysis (known as SOAP) though provided on almost every oil analysis report, is blind to severe wear particles. Severe wear particles may be few relative to the overall concentration of all wear present in a sample, however detecting them, understanding their source and severity provides users with the most advance prediction of an impending issue.

The Fieldlab platform has passed rigorous testing by the US Department of Defense and is now being rolled out as the next generation lubricant analysis standard. The Air Force have understood the spectrometer blind spot and augmented with other wear debris detection approaches, up to and including SEM (scanning electron microscopy) – a similar approach is widely used for commercial aviation oil analysis programs.

Importance of three facets of oil analysis

Oil analysis does not refer to one or two tests, rather a suite of tests chosen to ensure three aspects are addressed - as shown in Figure 2.

The Trivector™ is a very effective radar plot covering all aspects, thus enabling any equipment maintainer to quickly visualize the equipment health and immediately form an action plan to address abnormalities.

Figure 2: Trivector™ oil analysis: A powerful way to summarize data from all 3 facets of oil analysis by graphically illustrating direction and severity of faults, enabling quick decision making

Why focus on abnormal wear

Turbines, generators, pumps, motors, compressors, gearboxes, fans, couplings, rolls, screens, and other rotating, reciprocating, or articulating machines are prone to experience severe sliding adhesive wear, rolling fatigue wear, and bending fatigue fracture. It is common for defects to progressively transition in stages. Successive stages of severity involve increasing size ranges and increasing quantities of metal wear debris. Severity stages may be described as benign, severe, advanced, and then catastrophic wear debris.

Lubricants separate highly loaded machinery components. Severe sliding adhesive wear involves abnormal metal-to-metal wiping or sliding contact between moving components. Localized adhesive wear often takes place due to extreme loading, slow speed, absence of lubrication, low viscosity oil, or misapplication of lubrication.

Rolling fatigue wear is caused by high cycle rolling compression load such as between roller and raceway or between gear teeth in vicinity of the pitch line. Bending fatigue fractures are caused by low cycle fatigue crack propagation originating from a defect or stress concentration.

The graph in Figure 3 shows wear particle size range for stages of wear from benign to catastrophic. Abnormal abrasion, adhesion and fatigue wear debris particles are large and contain base metal. Microspall particles range between 10 μm and 50 μm. Laminar particles and chunks range from 50 μm to several hundreds of microns. It is important to collect samples during the prediction interval so repairs can be planned and accomplished before reaching the catastrophic stage when repairs and downtime are unavoidable.

What is the elemental composition of large abnormal abrasion, adhesion, and fatigue wear debris? Large ferrous wear debris from shafts, antifriction bearing rollers and raceways are primarily ferrous alloys. Most of the strongest, hardest, and toughest mechanical components are iron alloys. Many components essential for machine operation are composed of lead/tin "white" metal alloys and/or of copper alloy "yellow" metal. Common examples include worm gear, thrust bearing, radial bearing, and journal. Elemental analysis of large wear debris for wiped bearings, severe sliding, fatigue and abrasion wear debris primarily composed of Fe, Cu, Pb, Sn, and Si.

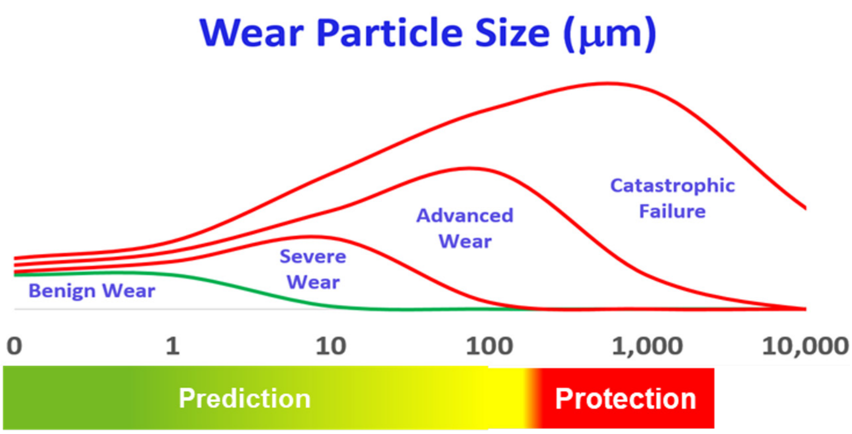


Figure 3: Severe, advanced and catastrophic wear debris size range from sub-micron to very large.

FieldLab 58C

The FieldLab 58C XRF module non-destructively analyzes common wear debris Fe, Cu, Pb, Sn, Si, Al, Cr, Ti, Ni, Mg, Mn, Ag, V, W, Zn and Co from 4-micron to millimeter size range. This range spans the severe and advanced stages of abnormal wear debris shown in Figure 2. Optical emission spectroscopic analysis is effectively blind to particles larger than about 5-microns. Since abnormal abrasion, fatigue, and severe sliding wear particles are nearly all larger than 10-microns, the FPQ XRF method adds tremendous value to the state of the art for elemental analysis of wear debris.

Filtergram measurement for onsite oil analysis

The FieldLab 58C uses a filtergram particle quantifier with X-ray fluorescence (FPQ XRF) to performs pore blockage particle counting followed by energy dispersive X-ray fluorescence multi-elemental analysis per ASTM D7684, ASTM D8127 and ISO 21018-3.

Figures 4a and 4b shows the filtergram particle quantifier (FPQ) having an active area portion of the 4-micron filter membrane where wear debris accumulates. The FPQ specimen is labeled, XRF elemental analysis is performed, and the specimen is retained for visual and microscopic examination.

The Fieldlab 58C FPQ serves three purposes: pore blockage particle counting, x-ray fluorescence wear debris analysis, and specimen for viewing and further analysis as needed. Combined with the chemistry and viscosity results, the Fieldlab 58C provides a very detailed picture of machine components, system contamination, and lubricant condition. This rich information, with built-in diagnostics providing real actionable findings, empowers onsite personnel to begin planning for repairs or design change.

The FieldLab 58C results are in the predictive range of sensitivity that enables the team to buy time. In real terms this means normal priority task scheduling, and when implemented, avoids high risk and expense. This FieldLab is designed to provide comprehensive data for TriVector™ analysis reports. A rugged tablet onboard streamlines workflow, and controlling all modules, compiling data to analyze it in situ, with the added benefit of integrating neatly with TruVu 360 fluid intelligence system, which manages asset analysis data and alarms.

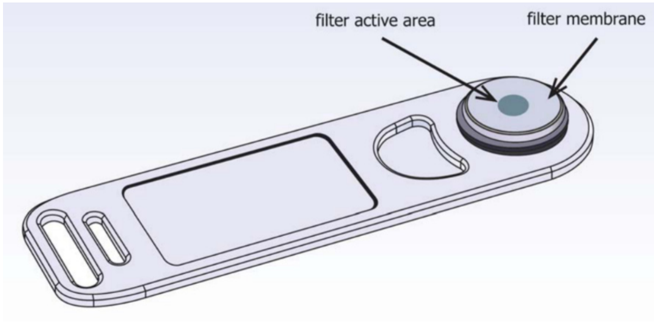


Figure 4a: Iris Filtergram for pore blockage particle count and x-ray fluorescence, FPQ XRF, using FieldLab 58C

Figure 4b: Inserting FPQ Filtergram for XRF x-ray fluorescence.

Large particle wear debris sampling methods

Use the best active zone sampling method for sampling large particle wear debris.

Brownian motion disperses sub-micron to five-micron metal oxide debris benign wear debris in oil compartments and oil sample bottles.

However, large wear debris are primarily metal, not oxide, and they settle in oil compartments and in sample bottles. Abnormal abrasive, adhesive, and fatigue wear particles are metal alloys such as ferrous alloys (containing iron), yellow metal alloys (containing copper), and white metal alloys (containing lead and tin).

It is important to sample an active zone where freshly generated wear particles are most likely produced. When practical sample circulating oil systems from the return line, before the oil reaches the large oil compartment. These systems often have an oil filter between the compartment and the machine, so the oil coming into the machine is relatively cleaner than the compartment oil. By sampling the return line, debris from actively wearing components will be flowing with the oil in the return line. Sampling the return line in circulating oil is strongly advised considering 5% of the lubricant is in the machine and more than 95% is in the large oil compartment, and a fundamental purpose for the compartment is to separate water and particulate from the oil in the compartment.

Active zone oil sampling from oil compartments is performed when the oil is up to temperature and running, or if not running, within a few minutes after shutdown.

Avoid unplanned repairs using multi-element FPQ XRF large wear debris analysis

The components shown in Figure 5, gear, shaft, antifriction bearing, and plane bearing, are responsible for failures of mechanical systems after undergoing extensive severe sliding, rolling fatigue, and bending fatigue wear debris much larger than 10-micron size. Elemental composition for components of these types is shown along with failed component images and descriptive images.

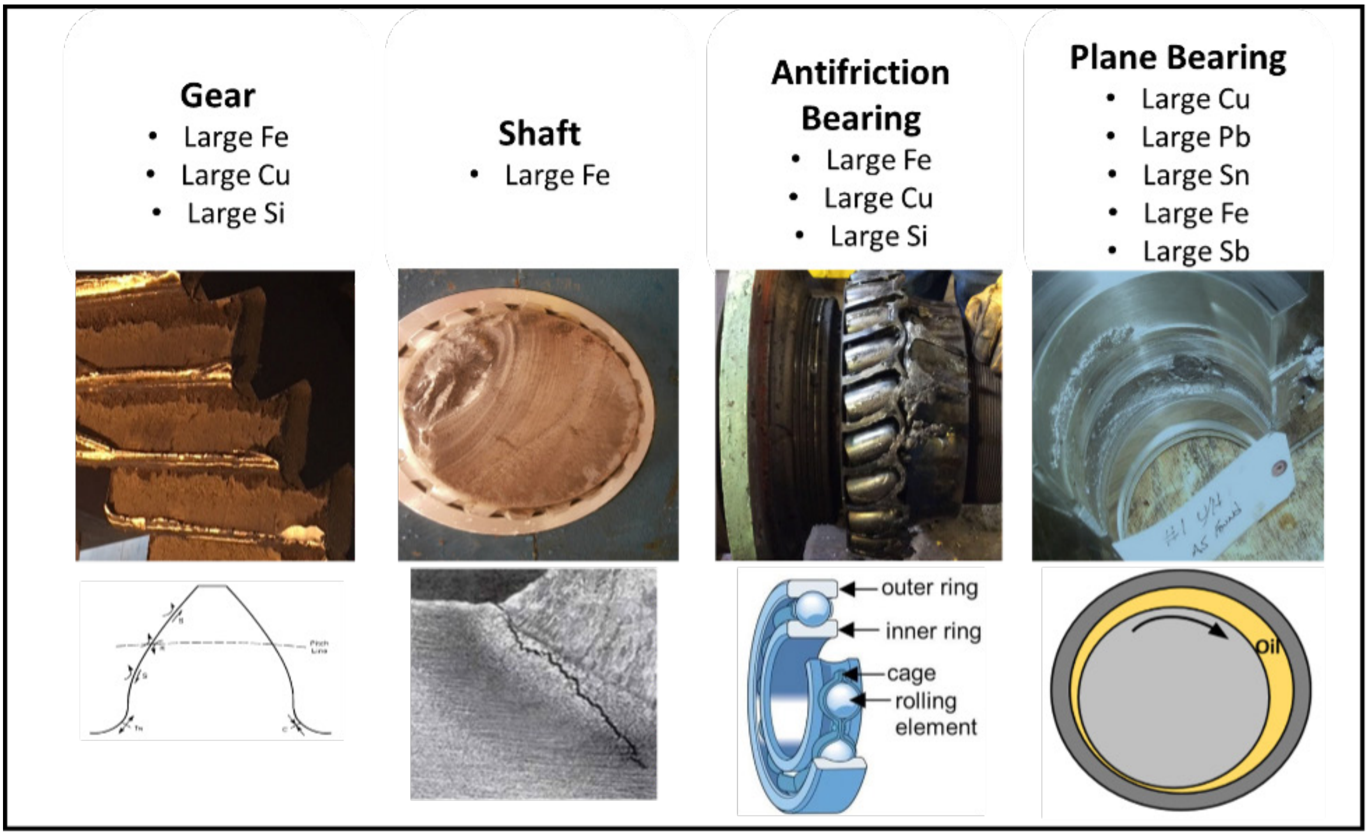


Figure 5: Avoid unplanned repairs for gears, shafts, and bearings using multi-element FPQ XRF.

Severe sliding and fatigue failures	Cost of unplanned repair and lost production	Elemental composition
First 20 MW turbine radial, journal, & trust bearing failures	55 days	Pb, Sn, Fe
Second 20 MW turbine thrust bearing failure	$95,000	Pb, Sn
Feedwater pump thrust bearing and seal failure	$106,000	Pb, Sn, Fe
Queen roll bearing failure	$354,000	Fe, Cu

Table 1. Examples of failures where proper sampling and multi-element large wear debris analysis might avoid unplanned repair and lost production costs.[3]

First 20 MW turbine generator radial, journal, thrust bearing failures

The first 20 MW turbine generator experienced failure of radial, journal, and thrust bearings. Service outage for repair required 55 days, however costs were not reported. Figure 6 shows the failed #1 bearing, Figure 7 shows the wiped active and inactive thrust bearings, and Figure 8 shows the wiped #2 bearing and journal. Steam turbine generator radial bearing was wiped, active and inactive thrust bearings were wiped, and journal was severely damaged - all due to severe sliding wear. Situations of erratic control and rotor dynamics were likely causes and symptoms of multiple wiped bearings.

Figure 6: Wiped #1 bearing.

As found #1 bearing

Figure 7: Wiped thrust bearing.

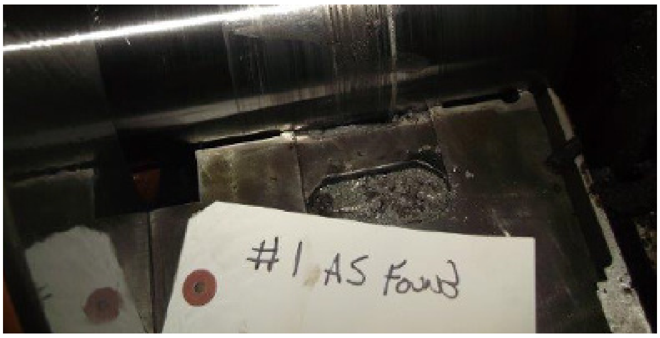
Active thrust (AF)

Inactive thrust (AF)

New active thrust

New inactive thrust

Figure 8: Wiped #2 bearing journal.



#1 journal (as found)

#1 journal (as left)

#2 bearing & journal (as found)

Second 20 MW turbine generator thrust bearing failure

The second 20 MW turbine generator bearing failure cost included $73,000 for repair and $21,000 production loss for total cost of $95,000. Axial thrust during transient operating conditions, wiped the thrust bearing. A bearing temperature sensor identified adhesive event. Immediate precautions and preparations were made for turbine to be shut down and opened for unscheduled, repair. The incident which caused the problem seems to be related to abnormal or extreme transient conditions.

Bingham feedwater pump thrust bearing and seal failure

The Bingham feedwater pump thrust bearing and seal failure costs was $106,000 for repair and no reported production loss. The outboard seal and the outboard thrust bearings were worn resulting in a feedwater leak and the pump locking up. The immediate cause of the failure was thrusting of the pump towards the thrust end. Although the lack of proper priming/warmup has most likely been a common occurrence on these pumps since installation and has never caused a similar failure immediately after an outage, it is determined to be the most likely root cause of the failure, whether it was this single occurrence that caused it or the accumulation of multiple instances. Removal of the pump cap revealed that the shaft had thrusted towards the thrust end, as indicated by several impellers rubbing against the casing towards the pump thrust end. Further evidence of pump thrusting was found on the inboard seal, indicated by the shaft collar contacting the seal body while running and causing bluing of both pieces. It was evident from the wear faces that the pump thrusting occurred before the seal failure.

Queen roll bearing failure

The costs due to failed queen roll bearing shown in Figure 8 were $30,000 for repair, production loss $324,000 and total $354,000. Figure 9 image shows catastrophic wear debris was generated during failure sequence from copper alloy cage and iron alloy bearing components. The roller bearing cage failed due to inadequate lubrication. Vibration data was taken 3 days prior to the failure. Inspection of the bearing revealed that the cage had failed with severe sliding wear.

Figure 9: Queen roll bearing cage failed due to lack of lubrication

Conclusion

The FieldLab 58C is the newest onsite solution designed to detect abnormal wear, contamination, viscosity and fluid chemistry in oil lubricated system as early as possible. Its portability, combined with a solvent free test approach, small sample volumes, quick tests, ass automatically alarmed and reported on device, as well as uploaded to TruVu 360 Fluid intelligence system, provides the ideal tool for maintenance personnel looking to start on enhance their reliability programs.

References: 1) "The bill is coming due" Garvey, R. Lubrication & Fluid Power November 2005 2) http://themilitaryengineer.com/index.php/item/555militarysealiftcommand%E2%80%94savingtimeonoilanalysis?tmpl=component&print=1 3) Garvey, Ray, Consulting Engineering case studies.

For more info visit: **www.spectrosci.com/fieldlab**

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