Recommended Practice: Filter Debris Collection and Analysis for Gearbox Condition Monitoring

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“The oil filter is a potentially rich source of information about the health of oil-wetted components . . . but is generally under-utilized as a condition monitoring (CM) tool . . .”[1]
• It is cost effective
• It requires low maintenance
• It is time efficient

AND . . .

Photo by Dennis Schroeder, NREL #49389
Labs offer test procedures
Standards have been written
Equipment suppliers have equipment

HOWEVER . . .

CM FDA program must be properly implemented and executed
To date, no wind-specific recommended practices available
NREL/Drivetrain Reliability Collaborative (DRC) draft FDA Recommended Practice (RP)

- Collective experience from DRC
- Recent NREL research with FDA
- Industry partnerships
- Wind site data partners
Basis for recommended practice

• Existing standards and RPs
• Commercially available lab analysis
• Gearbox sampling equipment
• NREL compact FDA testing
  o Equipment
  o Test methods

1 SCOPE
1.1 This guide pertains to removal and analysis techniques to extract debris captured by in-service lubricant and hydraulic filters and to analyze the debris removed[2].

AWEA Operations and Maintenance Recommended Practices, Chapter 8 Condition Based Maintenance

• RP 801 Condition Based Maintenance (CBM)
• RP 818 Wind Turbine Online Gearbox Debris Condition Monitoring
• RP 819 Online Oil Condition Monitoring
Three-lab survey (SGS Herguth, Gastops, Testoil)

• Gravimetric analysis
• Particle count, size, mass, and type
• Atomic emission spectroscopy (AES)
• Inductively coupled plasma (ICP)
• Energy dispersive X-ray fluorescence (EDXRF) elemental analysis
• Scanning Electron Microscopy, Energy Dispersive (SEM/EDS) for particle size, shape, and elemental composition
Wear debris collection

- Filter element
- Filter particle tray
- Magnetic dipstick
• Magnetic sleeve on main gear oil filter
• Side stream from sample collection port
• Magnet sweep of filter housing or sump
NREL compact filter for debris analysis (cFDA)

- Three field trials
- Five years
- Ten wind turbines
- Two analysis laboratories
FDA for Gearbox CM: NREL FDA Test Program

- Compared large filter data to compact filter data
- Favorable results
CM goal: Move beyond event-based maintenance strategy to avoid catastrophic failures

Checklist to determine whether FDA is a good addition for a typical wind plant:

• Is oil analysis providing preliminary failure warnings?
• Is filter clogging providing early-enough warning?
• Is the magnet picking up particles from all applicable failure modes?
• Are particle tray data being measured and recorded?
• Is the vibration system missing planetary failures?
Step 1: Gather information

• Identify and evaluate effectiveness of existing CM
  o SCADA (chip detectors, filter bypass, differential pressure)
  o Filters (main or side stream) and magnets
  o Online particle counting

• Track gearbox history by make and model
  o Failure modes, age, wind regime, oil condition history (ISO particle count, water, metals)

• Generate CM budget
Step 2: Scope FDA program within budget, need, and entire oil CM program

• Start with additional oil sample analysis (understand limits!)
  o Ferrography, particle count, elemental

• **Add FDA, offline**
  o Select hardware, determine access
  o Select laboratory, identify analysis methods

• **Add online wear particle counter**
  o Per-turbine basis triggered by FDA may reduce capital outlay
  o Support online data with hard evidence from FDA
Step 3: Determine particle collection method

• Eliminate inconsistent methods such as sump sweeps or wiping magnets with a rag

• Select system based upon existing hardware, logistics, and analysis costs
  o Particle tray (consistent samples?)
  o Magnet (ferrous limitation?)
  o FDA large filter element (low up-front cost but high long-term logistics and evaluation?)
  o Dedicated particle trap (i.e., side stream filter, magnet, or both)
Step 4: Specify analysis protocol

• Create lab statement of work
  o Authorize basic level (count, weight, mass, type)
  o Trigger detailed levels (microscopic, elemental composition)

• Start at low cost *then* trigger more specific testing, per ASTM D7919-14
  o Visual (in house?)
  o Count, weight, mass, type (automated)
    ➢ Ferrous or non-ferrous, counts, bins by size and type, and provides relative mass (ferrous)
  o Microscopic
    ➢ Ferrography, Scanning Electron Microscopy (SEM) with Automated Feature Analysis (AFA)
  o Elemental and alloy composition
    ➢ SEM with Energy Dispersive X-Ray Spectroscopy (SEM/EDX), AES, Inductively coupled plasma (ICP), X-ray Fluorescence (XRF)
(Step 4 continued)

- Confirm lab can process site debris collection format
  - Large filter
  - Compact filter
  - Field-prepared patch

- Confirm lab sample preparation provides consistent results
  - All collected debris needs to be counted
  - If back flushing, filter size limitations
  - If ultrasonic bath, entire or partial filter

- Normalize particle count data for production or operating hours?
Step 5: Establish baseline debris profile

- **Write collection protocol**
  - Consistent periodic samples
  - Sample interval (6 months)

- **Select proxy machines**
  - Highest production, several of each make/model gearbox

- **Collect supporting data**
  - Production, oil change, filter change, repair, extraordinary loading events

- **Compare and validate oil sample analysis with FDA**
Step 6: Monitor basic data, identify outliers

• Screen for additional analysis with visual and automated counting (level 1)

• Perform microscopic wear particle characterization on pre-screened equipment (level 2)
  o Run-in or failure?
  o Rubbing, surface fatigue, corrosion, sliding, cutting
  o Use to inform visual inspection

• Perform elemental and alloy composition if additional information adds value (level 3)
  o Bearing vs. gear? Cage?
  o Use to inform visual inspection
Step 7: Take action based on alarms

- Visually inspect gearbox (use FDA to inform)
- Add CM equipment to gearbox (wear particle, vibration)
  - Online or portable?
- Reduce power output, or make other turbine control parameter changes
- Repair gearbox

Step 8: Close gaps

- Review collection, analysis, alarms, and action steps
- Develop return on investment (ROI) studies for management
Call for innovation (and floor discussion)

• Sample filters, e.g., NREL cFDA, tailored for FDA

• Filters with removable diagnostic layer (e.g. Pall Dirt Alert™ for wind turbines)

• Sleeves on magnetic sticks to facilitate ferrous particle collection (see Figure 6, in reference 1)


Thank You!

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