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

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Drivetrain Reliability Collaborative Meeting

February 20–21, 2018

NREL/PR-5000-71098

Filter Debris Analysis (FDA) for Gearbox Condition Monitoring

“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]

FDA for Gearbox CM

- It is cost effective
- It requires low maintenance
- It is time efficient

AND . . .

Photo by Dennis Schroeder, NREL #49389

FDA for Gearbox CM

- 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
    - Equipment
    - Test methods

ASTM D7919 – 14 (Reapproved 2017), Standard Guide for Filter Debris Analysis (FDA) Using Manual or Automated Processes

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].

2. ASTM D7919-14(2017), Standard Guide for Filter Debris Analysis (FDA) Using Manual or Automated Processes, ASTM International, West Conshohocken, PA, 2017, www.astm.org.

FDA for Gearbox CM: Existing RPs

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

Main gear oil filter
Photo by Don Roberts

Magnetic dipstick
Photo by Don Roberts

Filter particle tray
Photo by Don Roberts

FDA for Gearbox CM: Gearbox Sample Collection

- Magnetic sleeve on main gear oil filter
- Side stream from sample collection port
- Magnet sweep of filter housing or sump

Side stream
Photo by Don Roberts

Magnetic sweep
Photo by Don Roberts

FDA for Gearbox CM: NREL FDA Test Program

NREL compact filter for debris analysis (cFDA)

- Three field trials
- Five years
- Ten wind turbines
- Two analysis laboratories

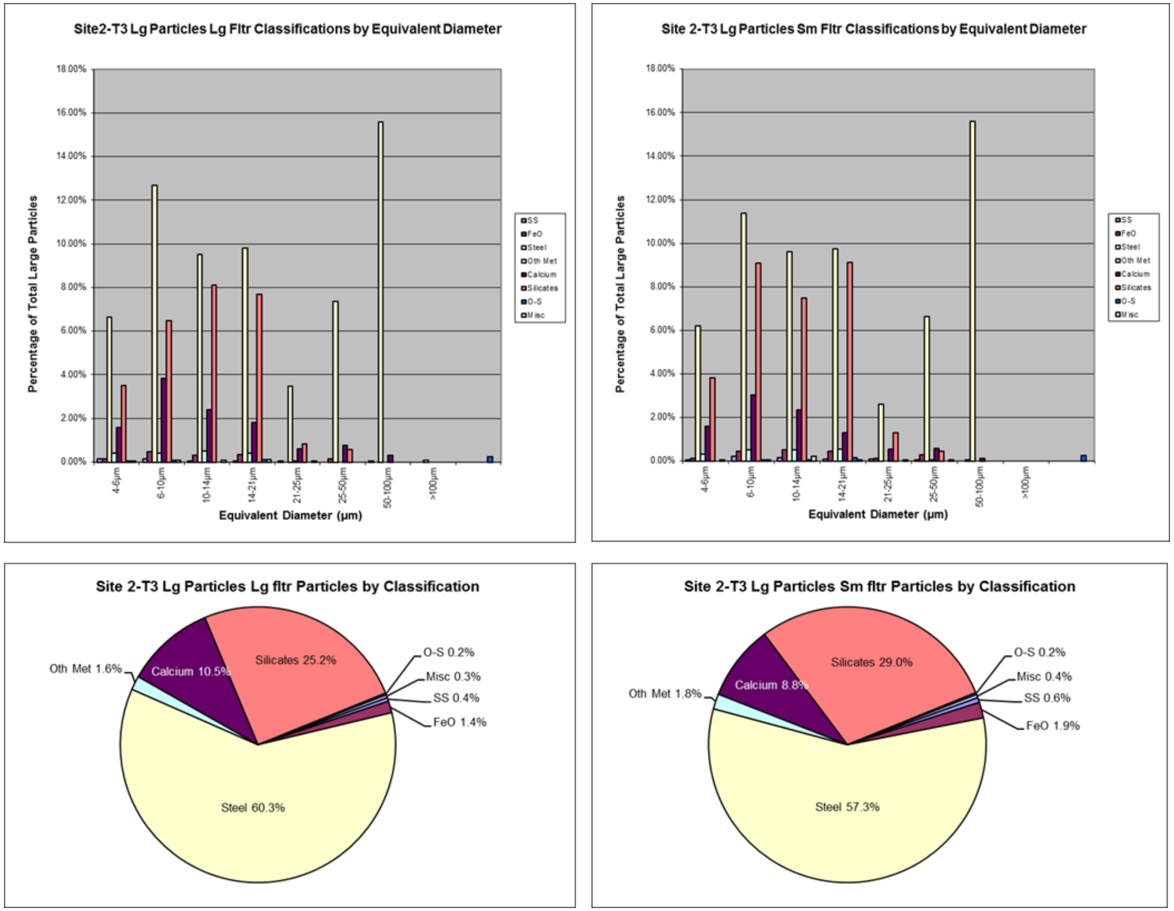
Photo by Don Roberts

Photo by Don Roberts

Photo by Dennis Schroeder, NREL 50696

FDA for Gearbox CM: NREL FDA Test Program

- Compared large filter data to compact filter data
- Favorable results



FDA for Gearbox CM: Draft RP Outline

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
  - SCADA (chip detectors, filter bypass, differential pressure)
  - Filters (main or side stream) and magnets
  - Online particle counting
- Track gearbox history by make and model
  - 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!)
  - Ferrography, particle count, elemental
- Add FDA, offline
  - Select hardware, determine access
  - Select laboratory, identify analysis methods
- Add online wear particle counter
  - Per-turbine basis triggered by FDA may reduce capital outlay
  - 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
  - Particle tray (consistent samples?)
  - Magnet (ferrous limitation?)
  - FDA large filter element (low up-front cost but high long-term logistics and evaluation?)
  - Dedicated particle trap (i.e., side stream filter, magnet, or both)

Step 4: Specify analysis protocol

- Create lab statement of work
  - Authorize basic level (count, weight, mass, type)
  - Trigger detailed levels (microscopic, elemental composition)
- Start at low cost *then* trigger more specific testing, per ASTM D7919-14
  - Visual (in house?)
  - Count, weight, mass, type (automated)
    - Ferrous or non-ferrous, counts, bins by size and type, and provides relative mass (ferrous)
  - Microscopic
    - Ferrography, Scanning Electron Microscopy (SEM) with Automated Feature Analysis (AFA)
  - Elemental and alloy composition
    - SEM with Energy Dispersive X-Ray Spectroscopy (SEM/EDX), AES, Inductively coupled plasma (ICP), X-ray Fluorescence (XRF)

FDA for Gearbox CM: Draft RP Outline

(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)
  - Run-in or failure?
  - Rubbing, surface fatigue, corrosion, sliding, cutting
  - Use to inform visual inspection
- Perform elemental and alloy composition if additional information adds value (level 3)
  - Bearing vs. gear? Cage?
  - 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

FDA for Gearbox CM: Looking Ahead

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)

FDA for Gearbox CM: Further Reading

1. Becker, Andrew and Peter Stanhope. “Improvements to Filter Debris Analysis in Aviation Propulsion Systems.” DSTO-TR-2773. Air Vehicles Division Defence Science and Technology Organisation. December 2012 (Unclassified).
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8. Toms Allison M., and Michael P. Barrett. “Using Filter Debris Analysis to identify Component Wear in Industrial Applications.” Insight Services white paper.
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Thank You!

Special thanks go to the U.S. Department of Energy, Hydac USA, SGS Herguth, Testoil, Gastops, Gemini Energy Services, and other filter debris analysis research partners!

Photo by Don Roberts

This presentation was supported by the U.S. Department of Energy (DOE) under Contract No. LHQ-7-70177 with the National Renewable Energy Laboratory. Funding for the work was provided by the DOE Office of Energy Efficiency and Renewable Energy, Wind Energy Technologies Office. The authors are solely responsible for any omissions or errors contained herein.

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