Oil Debris Condition Monitoring For Wind Turbine Gearboxes

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What's the Problem?

Gearbox Failures

Corporate Profile

- Advanced products and services for Machinery Condition Assessment and Control
- Supplier of MetalSCAN Oil Debris Monitoring technology since 1995
- Aviation, Defense, Energy and Marine sectors
- Founded in 1979
- Four locations:
  - Ottawa, Ontario (head office)
  - Halifax, Nova Scotia (field office)
  - Victoria, British Columbia (field office)
  - Pensacola, Florida (GasTOPS, Inc.)
Overview

- How can the problem be managed
- Condition Monitoring Theory & Feasibility
- Oil Debris Monitoring (ODM) method - principle of operation
- Why Bearings & Gears Fail
- Validation of ODM method for condition monitoring

How to deal with the problem?

- Conduct root cause investigations of gearbox problems
- Continue to make design modifications to gearboxes and their system interfaces
- Operators/owners must seek solutions to manage the problem

How can the problem be managed?

- Adopt Condition Monitoring (CM)
- Avoid “Failure” Event
  - Contain the damage
  - Reduce repair time & costs significantly
- Minimize Business Interruption
  - Schedule repair support on-site before shutdown
  - Minimize lost revenue & penalties
**Condition Monitoring Theory: P-F Curve**

- Need to have a: ‘Condition Indicator’ (CI)

**CM Technical Feasibility Criteria**

- CI must detect the potential failure (P)
- CI must identify the degree of damage towards failure (F)
- P-F interval must provide adequate time for the organization to proactively plan
- P-F curve must be consistent for the failure mode

**Oil Debris Monitoring (ODM) - Principle of Operation**

- Sensor includes 3-coil assembly
- Metallic debris from bearing or gearbox sump flows past the field coils creating a disturbance signal in the sense coil
- Signal characteristics define:
  - particle size based upon signal amplitude
  - type (Fe or NFe) based upon signal direction

**How does ODM satisfy the CM criteria?**
Why Bearings/Gears Fail?

- Most bearings/gears are damaged in-service due to stress concentrations that arise from:
  - Physical / dimensional discrepancies - Misapplication, Mishandling, Defects
  - Overrolling of debris - Contaminants in lube oil
  - Corrosion pitting - Chemical interactions

Validation of ODM method

- Bearing and Gear component damage - research data
- Engine and Gearbox damage - rig test data
- Fielded Applications damage – field data

Bearing and Gear Component Damage Research

Observations:
- Early damage is series of ‘particle bursts’
- Rate is dependent on load and speed
- Quantity is dependent on size of bearing
- Particle size distribution is independent of bearing size

Conclusions:
- Quantity correlates to ‘degree of damage’
- Quantity + Rate correlates to ‘remaining life’

Reference document: "Rolling Element Bearing Failure Detection with ODM (Oil Debris Monitor)" IMR-MCM-CTR-020
Gear Damage Research (NASA)

- Seeded fault test data from gear rig monitored by ODM

Bearing Prognostics Research (AFRL)

- Seeded fault test on bearing test rig
- 52100 and M50NiL bearing steels
- ODM used to monitor debris quantity

AFRL Observations-
1. Higher stress = quicker damage progression
2. Mass loss is repeatable for constant stress

Reference document: "ISHM presentation by Dr. Nelson Forester, Aug 11/05"

Engine and Gearbox Damage Rig Tests

Gas Turbine F119 (F22 Aircraft)
Bearing Damage – Test Data (P&W)

- New engine run on test stand
- Damage due to misassembly
- Bearing highly overstressed
- NO SECONDARY DAMAGE occurred
Bell 206 Helicopter Gearbox Bearing Damage – Test Data (DSTO)

- Rig test of two B206 main rotor gearboxes at DSTO test facility
- 150% overload stress test
- Test #1 & 2 teardowns showed damage limited to planet bearing

Apache Helicopter Gearbox Bearing Damage – Test Data (NAVAIR)

- Rig test of AH-64 drive-train at US Navy Patuxent River transmission test facility
- 200 hour high stress component qualification test
- Gearbox ran for ~50 hrs with only small quantity of bulk debris detected
- No chip detector alarm
- Teardown confirmed damage limited to input shaft bearing

Fielded Applications Damage Experience

Proven Oil Debris Monitoring (ODM) Applications for Rotating Equipment
Facts about the Equipment Bearing and Gear Damage

- Rotating Equipment suffer bearing or gear events periodically, often without warning.
- Depending upon the equipment application the cost of each undetected event can be in the hundreds of $000.
- Experience shows that damage develops progressively over time... days, weeks or months from initiation to failure, depending upon the equipment type.
- Operators/owners require early detection solutions to Proactively Manage the event and Avoid the Failure.

Gas Turbine FT8 (JT8D derivative)
Bearing Damage – Field Data

- Initial Damage
- Only last 100 hrs shown
- Engine ran for ~5000 hrs with virtually no debris detected.
- Operator ran past Alarm Limit to convenient shutdown period (weekend)
- NO SECONDARY DAMAGE occurred

Marine Propulsion Pod
Bearing Damage - Field Data

- 2 sensors per pod, one per bearing

Wind Turbine
Gearbox Damage – Field Data
**Summary**

- ODM has been proven to be a technically feasible condition indicator of damage for bearings and gears.
- ODM provides an EARLY indication of damage and quantifies the SEVERITY and RATE of damage progression towards failure.
- ODM is interpreted easily as a condition indicator to answer 2 essential questions:
  - Can the machine be operated?
  - If so, for how long?

**History of a Failure - Planetary Stage Bearing Damage**

- Inner Race
- Roller

Damage limited to:
- one planetary stage bearing &
- one planetary stage gear

**History of a Failure - Planetary Stage Gear Tooth Damage**

Damage limited to:
- one planetary stage bearing &
- one planetary stage gear

**History of a Failure - At Removal**

- 140,000 total particles counted
- 1,500 particles/day in later stages
- 8 months operation from detection of initial damage to removal