On-Line Sensors for Condition Monitoring

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Introducing Kittiwake

Measuring, Monitoring & Managing...

- Oil Sampling and Field Testing
- Water Sampling and Field Testing
- Lab and Field Wear Debris Analysis
- Online Oil & Wear Debris Analysis
- Laboratory Logistics
- Research & Development
Training and Education Oil Samples to Check Machine Health

Laboratory Oil Testing Instruments

On-board Oil and Vibration Machine Monitoring Sensors

Diagnoses by Prescient™

Machine Condition Reports

Global Solutions for Condition Monitoring Services and Support
Online Oil & Wear Debris Analysis

ANALEXrs

- Online Sensor Technologies - The ultimate in Condition Monitoring
- Real Time measurements
- In Remote Locations
- Multiple outputs for data collection

Online Analysis of:
- Ferrous & Non Ferrous Wear Debris
- Particle Count
- Oil Condition
- Moisture
What we will be talking about?

- Range of ANALEXrs wear debris sensors
- Technology behind the sensors
- Sensor development
- Features
- Sensor history
- Real life testing
- Summary and questions
What we will be talking about?

- Range of ANALEXrs wear debris sensors
- ANALEXrs Oil Condition sensor
- ANALEXrs Moisture sensor
- Technology behind the sensors
- Sensors Development
- Real life testing
- Realising cost benefits from sensor technologies
- Interfacing sensors
- Summary and questions
ANALEXrs
Total Ferrous Debris Sensor

Remote Sensors - the online link between your machines and ultimate reliability
ANALEXrs Wear Debris Sensors

Two base sensors which share similar
- Sensing technologies
- Parts
- Inputs and outputs
- Connection Wiring
- Potential customers

But with different
- Detection methods
- Data output
- Potential applications
Philosophy
- Measurement of total ferrous debris by Magnetometry reporting output in ppm
- On-line technology
- Automatic operation
- No chemicals

Technology
- Measures >5 micron (unlike ICP)
- No radioactive source (unlike XRF)
- Linear response
- Independent of oil flow speed

Outputs
- CAN interface
- 4-20 mA, RS232, RS485
- Radio link with built-in web server

Base models
- Two base models
- Targeted at steel works, large marine engines, wind turbines, gear boxes
Kittiwake asked by ExxonMobil to produce an on-line iron sensor for trending scrapedown oil.

Generation 1 designed, made and tested successfully on a land based test engine

Laboratory tests successfully completed at steel works

5 generation 1 sensors fitted to a slow speed marine diesel

2 generation 1 units fitted to a nuclear submarine gearbox

Generation 1 re-designed, improved, and produced to become generation 2

5 generation 2 fitted to the same slow speed marine diesel and all 10 sensors connected to a specialist data collection software on a CAN network
History Continued

- Piston version of sensor designed for installations where an using an air blast to zero is not available or appropriate
- Piston version successfully trailed by QinetiQ (Formally UK Defense, Evaluation and Research Agency). On an industry standard gear failure test rig.

Short term Future / Testing

- Continued support and receive data from the 10 sensors fitted to the slow speed marine diesel trials
- Trial with steel works to continue
- Trial of a piston sensor on a wind turbine gearbox with GE Wind to begin in approximately 1 month
- Sensor to be built into an automated oil sampling test rig to show correlation with the laboratory results
ANALEXrs Total Ferrous Debris Sensor

 FEATURES

- Robust cast iron enclosure providing strength and magnetic shielding
- Air Blast or Piston versions available for use in a multitude of applications
- 3/8” BSP connections for quick and easy installation
- Sealed to IP65 suitable for industrial use
- Reference coil for controlled temperature stability
- LED display providing a visual indication of sensor status
- Wide range of interface options due to variety of industry standard outputs

 APPLICATIONS

- Marine & Industrial Engines
- Gearboxes and Bearings
- Steel Production
- Power generation
Total Ferrous Piston Set-up

Potential fitting arrangement

- Piston sensor is suitable for almost all applications where customers already use PQ instruments
- Suitable for systems where no air is available or an air blast is inappropriate
  - Trains
  - Wind turbines (on and offshore)
  - Construction vehicles
  - Mining
Total Ferrous Piston Test set-up

- Installation on FZG gear test Rig
  - FZG = Forschungsstelle für Zahnräder und Getriebebau - Technical Institute for the study of Gears and Drive Mechanisms.
  - Industry standard gear testing rig
  - 12 load stages
  - 15 minutes a stage
  - Inspection at each stage to check on tooth wear
ANALEXrs Particle Content Sensor

**Philosophy**
- Measurement of individual wear debris particles to indicate the onset of machinery damage

**Technology**
- As particles enter a highly sensitive magnetic field they are detected due to their magnetic and conductive properties
- The magnitude and direction of spikes in magnetic flux indicate partial size and type
- Ferrous and non-ferrous wear particles counted separately and sized individually
- Non optical – Unaffected by Oil, Contaminant Type or Flow rate
  - Detects: >60µm (Fe) and >100µm (Non-Fe)
  - Temperature stable operation
  - Future possibilities to classify the material of the particle

**Outputs**
- CAN interface
- 4-20 mA, RS232, RS485
- Radio link with built-in web server
ANALEXRs Particle Content Sensor

**Features**

- 3/8” BSP connections for quick and easy installation
- Sealed to IP65 suitable for industrial applications
- Robust iron enclosure providing strength and magnetic shielding
- Wide range of interface options due to variety of industry standard outputs
- LED display providing a visual indication of sensor status

**Applications**

- Gearboxes and Bearings
- Turbines
- Steel Production
- Power generation
ANALEXrs Particle Content Sensor

History

- First prototype designed and successfully trailed at QinetiQ (Formally UK Defense, Evaluation and Research Agency).
- Tests carried out on the gearbox of the EuroFighter (Typhoon).
- Particles detected down to 60 micron (ferrous)
- Kittiwake acquires licence for the patented technology
- Kittiwake mechanically redesigns the sensor to have commonality of parts with the total ferrous sensor.
- Digital side of the PCB designed to include high speed data processing capabilities
- Particle detection software currently in progress
Volume of ball vs Pk-Pk Voltage - Carbide (Ferrous Channel)

- Voltage (V)
  - 1m/s
  - 2.5m/s
  - 4.5m/s

- Volume (mm^3)
  - 0.065
  - 0.13
  - 0.195
  - 0.26
  - 0.325
ANALEXrs Particle Counter Test Results

Speed vs Pk-Pk Voltage - Ferrous

Speed (m/s)
0 0.8 1 1.5 2 2.5 3 3.5 4 4.5

Voltage (V)
0 2 4 6 8 10 12

Materials:
- Chrome 0.5mm
- Brass 0.5mm
- Carbide 0.5mm
- CCR Steel 0.2mm
- RMB 0.3mm
- RMB 0.25mm
ANALEX<sub>rs</sub>
Oil Condition Sensor

Remote Sensors - the online link between your machines and ultimate reliability
**Tan Delta [30-200mhz]**

- Measures dielectric properties of oil at a fixed frequency
- Dielectric constant
  - ’Real’ [Energy storage]
  - ’Imaginary’ [Energy loss]

**Advantages**
- Ease of construction, robust and small
- Insensitive to contamination: large measurement path
- Contaminants have similar scale effects

**Disadvantages**
- Individual contaminants cannot be identified discretely

Tan Delta

tan δ @90°C, rising, with / without water - Mineral oil

Frequency (Hz)
Oil condition monitoring

- **Your needs...**
  - Reduce operating costs
  - Reduce failure nightmare
  - Measure, Monitor & Manage critical systems

- **Critical performance parameters**
  - Measurable
  - Consistent
  - Repeatable

- **On-line technologies**
  - Key indicators – trending
  - Real time
  - Work where man cannot

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Quantified as:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Number (BN)</td>
<td>50% Depletion</td>
</tr>
<tr>
<td>Acid Number (AN)</td>
<td>50% Increase</td>
</tr>
<tr>
<td>Insolubles (Soot)</td>
<td>0% - 2%</td>
</tr>
<tr>
<td>Glycol</td>
<td>0.05% - 0.5%</td>
</tr>
<tr>
<td>Water</td>
<td>0.05% - 1%</td>
</tr>
</tbody>
</table>
Integrated industrial solution

- Stainless steel housing – Rugged and long life performance
- Internal processing power – offers wide interface options
- High integrity sealing – using standard automotive techniques

- Widely used ½” BSP thread – Quick and easy installation to a wide range of machinery
- Gold oil sensing contact – long life and sensitivity
Wind turbine gear oil tests

- Oxidised samples tested
- Water contaminated samples tested 0.5% conc.

<table>
<thead>
<tr>
<th>Sample</th>
<th>TAN mg KOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.28</td>
</tr>
<tr>
<td>2</td>
<td>0.39</td>
</tr>
<tr>
<td>3</td>
<td>1.44</td>
</tr>
</tbody>
</table>
0.5% Water sample was lab simulated - turbomixed (high shear mixing) for 15 seconds shortly before measurement. Gear oil tested is a polyalphaolefin (PAO) synthetic. Measurements taken successively without turning sensor off – sensor head purged of previous test sample with dried and filtered (0.2µm) compressed air.
Automotive: Coolant and new oil

High Speed Diesel Engine with API CF-4 (MIL2104D)
Effect of coolant addition (0.5%) and New oil to Engine oil

- Sensor Response
- Oil Temp

Stop/Start Engine blip
Coolant added
Coolant evaporating from oil
New oil added
New oil settling with used oil
Time (sec)
Oil Temperature (°C)
Gearbox: water in Oil

Sensor output vs time
11kW motor into gearbox at 288rpm, 2 litres oil capacity
1% water addition.

Oil Quality Units

Oil Temperature

Days

Water added
Remote Sensors - the online link between your machines and ultimate reliability
Moisture sensor

- Relative humidity means before saturation
  - Dissolved water: some only detect free and emulsified water
  - No reagents

- Internal processing power – interface options

- Glass to metal hermetic seal
  - IP68
  - High pressure rating

- Performance
  - -40°C to 100°C
  - Temp sensing +/-1%
  - Saturation +/-2%
Sensor performance

Total Multagri Super 10W-30, Turbomixed Samples
Relative Humidity Probe

Water Added (ppm) vs. Meter reading (% Sat)

- Kittiwake
- Vaisala
Interfacing sensors

- Universal standard Analogue 4-20mA
- Digital CAN and RS232
- Wireless Communications
- Remote Sensing

- Link the sensors into control systems
  - Third Party software
  - Machine control systems
  - OEM’s
  - Data loggers
Technical Specifications and Applications

Typical applications:
The sensor will prove most valuable when used with machines that are either:

- A high capital cost
- Production critical
- Safety critical
- Costly to repair
- Have long lead times on spares.
- Remote locations

ANALEXrs equipment can be fitted on any machine with a circulating lubrication system, and where either ferrous or non-ferrous wear debris is a predominant measure of the wear rate. Alternatively, use the ANALEXrs range on a filter cartridge to assess condition of splash lubricated machines.

Examples include equipment such as:

- Engines
- Gearboxes & Transmissions
- Bearings
- Pumps
- Compressors
- Turbines

Industries such as:

- Power Generation (Steam, Nuclear, Wind turbine)
- Steel
- Pulp & Paper
- Petro-chemical/refineries
- Transportation
- Military
## Specifications

<table>
<thead>
<tr>
<th></th>
<th>Total Ferrous Debris Sensor</th>
<th>Oil Condition Sensor</th>
<th>Particle Content Sensor</th>
<th>Moisture Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detection</strong></td>
<td>Total Ferrous Wear Debris 0 - 2000ppm</td>
<td>Oil Condition 0-100 Oil Quality Units</td>
<td>Ferrous Particles &gt; 60µm and Metallic Non-Ferrous Debris Particles &gt; 100µm</td>
<td>0-100% Saturation</td>
</tr>
<tr>
<td><strong>Analogue Output</strong></td>
<td>4-20mA</td>
<td>4-20mA</td>
<td>4-20mA</td>
<td>4-20mA % saturation &amp; Temp of Oil</td>
</tr>
<tr>
<td><strong>Digital Output</strong></td>
<td>CAN, RS232, RS485, radio link</td>
<td>RS232, CAN</td>
<td>CAN, RS232, RS485, radio link</td>
<td>RS232, CAN</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>18-36 VDC</td>
<td>15-30 VDC, 1 watt max</td>
<td>18-36 VDC</td>
<td>12-24Vdc at 25ms</td>
</tr>
<tr>
<td><strong>Maximum Oil Pressure</strong></td>
<td>10 bar (145psi)</td>
<td>10 bar (145psi)</td>
<td>10bar (145psi)</td>
<td>10bar (145psi)</td>
</tr>
<tr>
<td><strong>Operating Temperature</strong></td>
<td>-25 to 85°C (-13 to 185°F)**</td>
<td>30 to 130°C (86 – 266°F)</td>
<td>-25 to 85°C (-13 to 185°F)**</td>
<td>-40 to 100 DegC</td>
</tr>
<tr>
<td><strong>Protection</strong></td>
<td>IP65</td>
<td>IP67</td>
<td>IP65</td>
<td>IP67</td>
</tr>
<tr>
<td><strong>Sensor Weight</strong></td>
<td>2.2kg (4.85lb)</td>
<td>250g (9oz)</td>
<td>1.4 kg (3.1lb)</td>
<td>250g (9oz)</td>
</tr>
</tbody>
</table>

**Kittiwake operates a continuous development program and thus certain specifications may be subject to change.**
Sensors can be used to predict failure, reducing unexpected equipment down time and labour costs.

Robust solutions for monitoring oil condition and moisture content.

Provide real time indicators of oil condition.

Robust solutions for monitoring debris in a myriad of applications.

Provide real time indicators of machinery condition.

Advanced connectivity to other sensors in the ANALEXrs Range.

These sensors are the solution to many current problems, and hopefully the solution for some new ones.