Fiber optical sensing

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SKF – a truly global company

- Established: 1907
- Sales 2015: Euro 8,287 Million
- Employees: 46,635
- Production sites: around 115 in 29 countries
- SKF presence: in over 130 countries
- Distributors/dealers: 17,000 locations
Our solutions are everywhere
SKF technology

Technologies around the rotating shaft
Changing business reality

**Globalization**
- More competitive landscape across the value chain
- Asian companies going global
- Overcapacity in heavy and investment-driven industries

**Technology**
- Automation, electrification and digitalization drive the change
- New technology requirements for new applications
- Technology for cost competitiveness

**Competitors**
- New, emerging competitors gaining ground
- Chinese competitors strengthen position fueled by local market

**Customers**
- More transparent supplier market gives stronger buying power
- Strong price/cost focus
- Tougher competition and SKF traditional customer base under competitive pressure
Two value propositions in focus

1. Rotating equipment performance

Customer need:
“I want your products and my assets to reach technical end of life with trouble-free operation”

2. Product

Customer need:
“I want on-time delivery, quality and field performance, flawless launches of new products, technology and price”
Smartifying industry

- Mobility becomes the window
- the Cloud becomes the infrastructure
- (Big) Data management becomes the intelligence
- Connected sensors/systems become the data feed
Monitoring the heart of your application

“Bearing unique control point of the application”
What to monitor in that heart

<table>
<thead>
<tr>
<th>Service</th>
<th>“Product &amp; service”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design verification and support tool</td>
<td>Process control</td>
</tr>
<tr>
<td>Trouble shooting</td>
<td>Condition monitoring &amp; prognostics</td>
</tr>
</tbody>
</table>

Operation: Load

Condition: Vibration
Fiber optical sensing
Fiber Bragg Sensing – principle

Interrogator

Unstrained FBG

Strained FBG

\[ \lambda_{\text{Bragg}} = 2n\Lambda \]

\[ \lambda'_{\text{Bragg}} = 2n'\Lambda' \]
Multiplex sensing

Up to 25 sensors per fiber
Technology integration
How do you measure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Process parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>Load</td>
</tr>
<tr>
<td># peak / min</td>
<td>Speed</td>
</tr>
<tr>
<td>Response shape</td>
<td>Defects</td>
</tr>
<tr>
<td>Temperature</td>
<td>Offset</td>
</tr>
<tr>
<td>Amplitude different sensors</td>
<td>Loaded zone</td>
</tr>
</tbody>
</table>

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Main sensing functionality in thrusters

Bearing loads

\[ L_{10} = \frac{1}{\left[ 1 + \frac{m L_{10}^{(m-1)} L_{e} \left( \frac{C}{P} \right)^{c} (a_d)^{c}}{\ln(1/0.9)} \right]^{1/e} a D \left( \frac{C}{P} \right)^{p}} \]

Load is the largest influence on bearing lifetime

Real application loads are often unknown, monitoring enables:

- Design optimization
- Bearing life – Condition based maintenance
- Optimal operating regime's
- Full control – lower cost/longer insurance period
- Fleet management – best practice optimization
- ….
Fiber Optical load Sensing

**Measurement performance**
- High signal-to-noise ratio
- Multiple variables: Load, temperature, pressure, vibration...
- Multiple sensors in one fiber

**Harsh /hard accessible environments**
- Intrinsic explosion safe
- Sub-water resistant
  - no corrosion
  - no signal issues from under water
- High chemical resistance
- Wide temperature range
- Robust against EM-interference
Pumps & Compressors

- One fiber for multi operating parameter sensing
- Large distances - submerged
- New type of pumps development

Value:
- No electro magnetic interference
- integrated into the bearing – small integration footprint
- large amounts of data
- One cable for Load, temperature, pressure and CoMo – One ingress
- No monitoring solution currently available – compressors
- Optimized operation/process control
Strain and speed measurement

- Able to identify roller speed.
  - Possible to identify bearing slip.
- The size of the loaded zone can be determined.
- Individual rollers can be identified by their signal strength.

![Diagram](image)

Figure 5 Example of strain signals
Condition monitoring

- High frequency content imposed on roller pass.
- Small pressure reduction visible.
- Calculated length of defect = ~2 μm
Jacking systems

• Load measurement during stand-still
• Absolute static load measuring without prior dynamic load information
• Absolute load as operating parameter

Value:
• Small footprint; integrated into the bearing
• Large amounts of data
• Direct measurement of load and load angle at the pinion
• Static load measuring possible due to sensor integration density (~2.5 mm)
• Harsh environment (salt water corrosion)
Application - Jacking systems
Application - Jacking systems

Two bearing position to measure **static and dynamic** load:
- Three stage spur gearbox
- At the pinion
Load estimate – guides are +/- 5%
Thruster pods monitoring

Vertical shaft
- Temperature
- Shock loads
- Load direction

Pinion shaft
- Temperature
- Shock loads
- Load direction
- CoMo

Propeller shaft
- Temperature
- Shock loads
- Load direction

Propeller shaft
- Temperature
- Shock loads
Load Measurement: Strain to Load

rotating axis  ➔  sensor signals  ➔  load measurement

radial load
axial load
moment
Measurements
Dis-balance in propeller shaft

Naming:
- 23138\(_0\) – Channel 0 pinion SRB
- 23138\(_1\) – Channel 1 pinion SRB
- 23044\(_0\) – Channel 0 Propeller SRB
- 23044\(_1\) – Channel 1 Propeller SRB
- 29336E – SRTB
Sensing value

Via a sensor bearing we can sense multiple operating parameters in thrusters;

- Load (Axial/Radial)
- Direction of loaded zone
- Torque
- Bearing temperature & OR temperature distribution
- Speed & direction of rotation

What can be done with this operating information?
## Purpose

1. Optimize operation
2. Optimize maintenance
3. Repair logistics
4. OEM – Design & Warranty
5. Optimize bearing design
6. Fleet mgmt & performance
7. Develop new certification rules
8. Understanding of insured object

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### Cloud

#### Data Clustering

**OEM** (Original Equipment Manufacturer)

**SKF**

**Fleet technical management office**

**First technical manager / Superintendent**

**LR** (Lloyd's Register)

**Chief engineer**

**The bridge**

**Repair shop**

**SKF Warehouse**

**Parts delivery**

**SKF sensing solution**

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Summary – Fibre optical sensing in Marine

An unique tool to monitor “unknown” thruster loads:

• Measuring “How your application is operated”

• Sensing is one, making sense of it is the complex part

• Multiple sensing; “You can get more then you expect”

• Sensors have to work:
  • At “impossible” situations
  • After extreme handling

• Internet-of-bearings