Together We Move The World

Monitoring of Spindle Bearings During Operation

Lecturer: Ehad Arifi, Schaeffler Technologies GmbH & Co. KG
Title: Monitoring of Spindle Bearings During Operation
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- Spindle bearing monitoring during operation
  - Targets and approaches
- Effects of bearing damages
- Possible monitoring parameters
  - Temperature, Vibration
- Vibration monitoring strategies
  - Basic principle of vibration monitoring
- Practical examples
  - Offline and Online vibration monitoring
- Schaeffler Technologies vibration monitoring products
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Condition Monitoring a tool of Condition Based Maintenance

Maintenance strategies:

✓ Running until failure
  ✓ Advantage: Effort only in case of failure
  ✓ Disadvantage: No maintenance planning possible

✓ Planned maintenance / Preventive maintenance
  ✓ Advantage: Failures can be avoided
  ✓ Disadvantage: In certain cases unnecessary effort

✓ Condition based maintenance
  ✓ Advantage: Optimum performance of components
  ✓ Disadvantage: Information about components necessary
Condition Monitoring a tool of Condition Based Maintenance

Targets and approaches from point of view….

Maintenance:
- Avoid unplanned shut downs
- Ensure and increase machine availability
- Information about machine components
  - Support for maintenance schedule and maintenance capacity
  - Maintenance without disturbing normal machine operation
  - Reduce of maintenance costs
  - Reduce stock of components
- Online monitoring of beginning damages of components

Production:
- Avoid disruption of production
- Increase productivity
- Reduce production costs
- Ensure product quality

Condition Monitoring
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Cause of spindle bearing failure

- Operating life time is limited in most cases due to wear
  - Sealing: Ingress of foreign particles
  - Lubrication: contaminants

- Indentation in raceways
  - Plastic deformation as result of static overload
e.g. crash
  - foreign particle cycling

- Material fatigue
  - pitting
  - crack
Normal raceway
Fatigue, pitting
Indication of bearing damage

- Reduction of workpiece quality
- Temperature profile
- Noise, Vibration
  - Due to fatigue and raceway damages
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- Vibration monitoring products of Schaeffler Technologies
Possible monitoring parameters

- Friction Torque

- Bearing temperature monitoring
  - Change of preload and malfunction of floating bearing generates typical temperature profiles

- Vibration monitoring / noise
  - Continuous monitoring
  - Periodic monitoring

- Characteristic value monitoring
- Frequency analysis
Bearing Friction Torque (coast down)
Temperature Monitoring

- Reference Temperature
- Contact to the measuring Object
- Temperature Developing
Temperature Monitoring

![Graph](image)

- **Run time [h]**
- **Temperature [°C]**

Legend:
- Green Circle
- Red Circle
- Black Circle
- Blue Circle
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## Targets - Vibration monitoring strategies

<table>
<thead>
<tr>
<th></th>
<th>One-Time</th>
<th>Periodical</th>
<th>Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Assurance</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Storing of Operating Conditions</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Damage Limitation</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Condition based maintenance</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Bearing arrangement of machine tool

Spindle bearing arrangement in machine tool
- Lathe machine
- Milling machine
- Drilling machine
- Grinding machine

Characteristic of spindle arrangement
- High running accuracy
- High stiffness
- Low running noise
  - at high turning speed

Consequential:
Definition of monitoring parameters and strategies
Source of noise in bearings

- Elastic deformation
- Friction, lubrication noise
- Surface effects
  - (change of contact surface, local damage, wear)
    - Surface of rolling element
    - Outer and Inner ring raceway
Cycling of surface effects

- **Damage on outer ring**
- **Damage on inner ring**
- **Damage on rolling element**

- Cycling of damages on surfaces generates impacts
- Impacts leads to losses of quality and higher running noise
- Even little damages may lead to strong quality problems
- Specified monitoring of bearing defect frequencies
- **Attention!**
  Progress of damage very fast on high speed applications
Specified damage bearing frequencies

<table>
<thead>
<tr>
<th>Bearing</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>20300-TVP</td>
<td>FAG</td>
</tr>
<tr>
<td>2206-E-X</td>
<td>FAG</td>
</tr>
</tbody>
</table>

Geometry data or damage frequencies:

- Inner race frequency: 7,570
- Outer race frequency: 5,490
- Roller frequency: 2,353
- Cage frequency at fixed outer race: 0.420
- Cage frequency at fixed inner race: 0.379

[Diagram of bearing and table data]
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Offline monitoring of spindles

- Offline measuring with Data collector
- Measurements on test rig
- Create database
  machine information, spindle number, bearing
  type and documentation spindle condition
- Combination of parameter monitoring and
  deep frequency analysis
Offline monitoring of spindles

- Measurements at same turning speed and same sensor position
- Trending of parameters and amplitudes of specified frequencies
- Right setting of monitoring configuration
Offline monitoring of spindles

- Periodic measurements with documentation
- Trending data and deviation
- As a result of frequency analysis, bearing damages are detected on time
Damage on bearing raceway

Measurement taken on work piece spindle

- Impacts as a result of damaged bearing are visible in the frequency spectra

Measurement taken after replacement of spindle bearing arrangement

- The vibration signal doesn't consist bearing defect frequencies
Online monitoring of tool spindles

- Online monitoring of stationary tool spindles with permanent installed sensors
- Monitoring of spindle bearings
  - Monitoring of overall vibration level
  - Frequency analysis
- Monitoring of unbalance (1x turning speed)
- Data communication via TCP/IP (Network)
  - Alarm information
  - Data transfer
Online monitoring of tool spindles

Measuring only during idle position at same speed:

- Measuring on idle position:
  - No additional vibration sources
  - Increased visibility of damage frequencies
  - Detection of incipient damages on bearings is possible
  - Spindle bearing frequencies can be separated

- Measuring on same speed:
  - Reliable data trending and alarm settings

Start button for measurement
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FAG Detector III – Monitoring and balancing with a single device
FAG Detector III – Functions

Vibration diagnosis

- Route planning
- Integrated bearing database
- Automatic alarm threshold adjustment
- Automatic selection of measuring points (RFID technology)
- Presentation of vibration data trends
- In-depth diagnosis
- Customer-specific measurement reports
FAG Detector III – Scope of delivery

FAG Detector III Kit*

- Base device with rechargeable battery
- Acceleration sensor with magnetic foot
- Contact-free (infra red) temperature sensor
- Power pack
- PC data cable (serial/USB)
- User manual
- Protective bag with holder for temperature sensor
- PC software Trendline
- RFID tags
- Case

*Available with and without RFID technology.
Please note: The RFID functionality is not available worldwide.

Complete diagnosis system

FAG Detector III Balancing Kit

- Acceleration sensor with magnetic foot
- Trigger sensor (optical and inductive)
- Weighing balance
- Magnetic holder for trigger sensor
- Extension for magnetic holder
- Cable for trigger sensor (length 10 m)
- Reflex mark for trigger sensor
- Dongle for activation of balancing function
- Case
FAG DTECT X1 s
FAG DTECT X1 s - Advantages

**New**

All necessary functions in one device:

- Monitoring from up to eight channels plus two additional channels
- Integrated rotary frequency input
- Improved overvoltage protection for power, additional signals and communication, sensor defect identification
- TCP/IP and serial communication (WiFi option)
- Extended operating temperature from -20 °C up to +70 °C for device environment
- Analog interfaces to process systems with optional galvanic isolation to protect control systems
- Protection class IP 67
FAG DTECT X1 s - Advantages

New

Small design:
- W: 260 mm x H: 150 mm x D: 90 mm

Standardized connection technology:
- Flexible and easy installation in the field through M12 connection sockets
- Isolation amplifier as separate modules upgradable in the field (adjustable: 0 – 10 V, 0 – 20 mA, 4 – 20 mA)

Compatibility to existing installations:
- Firmware and software
Safety through vigilance!
The time is ripe: vibration sensors on every machine
FAG SmartCheck – Products and services

FAG SmartCheck
Decentralized Monitoring of Machines and Processes

<table>
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<tr>
<th>QUICK installation</th>
<th>IMMEDIATELY ready for use</th>
<th>INTUITIVE operation</th>
<th>EASY retrieval of measured data</th>
<th>FAG SmartCheck App</th>
</tr>
</thead>
<tbody>
<tr>
<td>through easy mounting and little wiring</td>
<td>thanks to monitoring configuration template</td>
<td>thanks to status LEDs</td>
<td>e.g. via standard web browser</td>
<td>permits access to data via smartphones</td>
</tr>
</tbody>
</table>
**FAG SmartCheck – Products and services**

**Level 2**

**FAG SmartCheck**
Intelligent Process Integration

<table>
<thead>
<tr>
<th>Network capable and Power over Ethernet (PoE)</th>
<th>Integration into PLC / OPC</th>
<th>Gain information from data</th>
<th>Webinterface: FAG SmartWeb</th>
<th>Integration into control station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication and power supply via a single line</td>
<td>Data exchange OPC UA client server*</td>
<td>Various machine and process parameters are recorded and correlated with vibration signals</td>
<td>Analysis and diagnosis software permits remote access to FAG SmartCheck</td>
<td>Derivation of process control measures</td>
</tr>
</tbody>
</table>

* At the planning stage
## FAG SmartCheck – Products and services

**FAG SmartCheck**
- Full Service From a Single Source

<table>
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<th>Remote monitoring</th>
<th>Condition report</th>
<th>Services Reconditioning</th>
<th>Training courses</th>
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<tbody>
<tr>
<td>● Definition of measuring points</td>
<td>● Remote servicing (analysis and reporting)</td>
<td>● Preparation of condition reports</td>
<td>● System integration and adaptation</td>
<td>Standard and tailored to our customers’ needs</td>
</tr>
<tr>
<td>● Commissioning</td>
<td>● System maintenance (adjustment of alarm thresholds etc.)</td>
<td>● Written recommendations for action</td>
<td>● Integration related consultation</td>
<td></td>
</tr>
<tr>
<td>● Reference measurements</td>
<td></td>
<td></td>
<td>● Maintenance service</td>
<td></td>
</tr>
<tr>
<td>● Measuring rounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● System integration</td>
<td></td>
<td></td>
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<tr>
<td>● Investigation of the cause(s) of problems</td>
<td></td>
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**FAG SmartCheck – Products and services**

- System integration and adaptation
- Integration related consultation
- Maintenance service
- Training courses tailored to our customers’ needs
Together We Move The World

Thank you