eolotec
bearing technology

Monitoring of Blade Bearings

IWES Offshore R&D Conference

November 2018

Company Portfolio

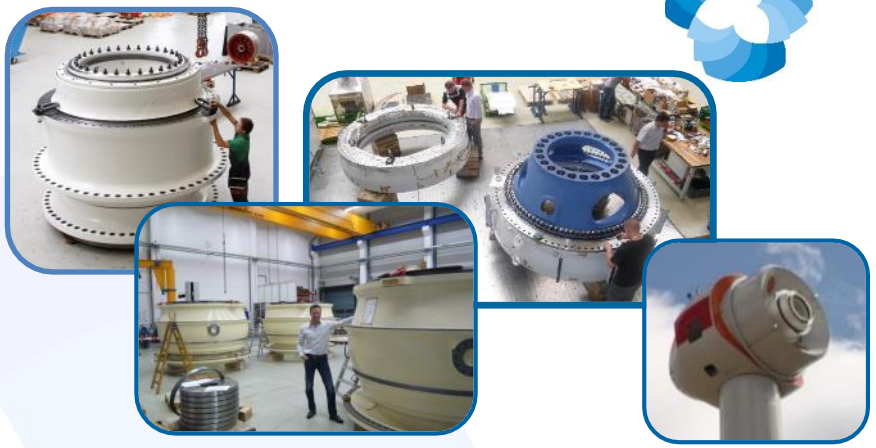
Eolotec GmbH

- Established 2012
- Bearing knowhow since 2004
- Focused on large wind turbine bearings
- Located in Nuremberg
- 10 employees
- Several awards
- Production in Germany
- Engineering, prototypes, series
- Bearing services and consulting
- On Demand R&D

Eolotec GmbH

Products

- **Bearing Systems**
  - Ready to mount Main Bearing Units (MBU)
  - Exchange solutions



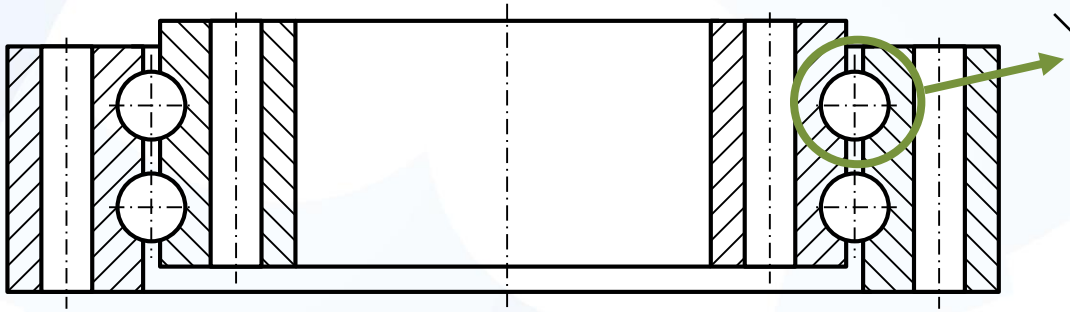
- **Lifting, testing, assembling**
  - Rotor-mounting
  - Generator lifting
  - Blade bearing testing

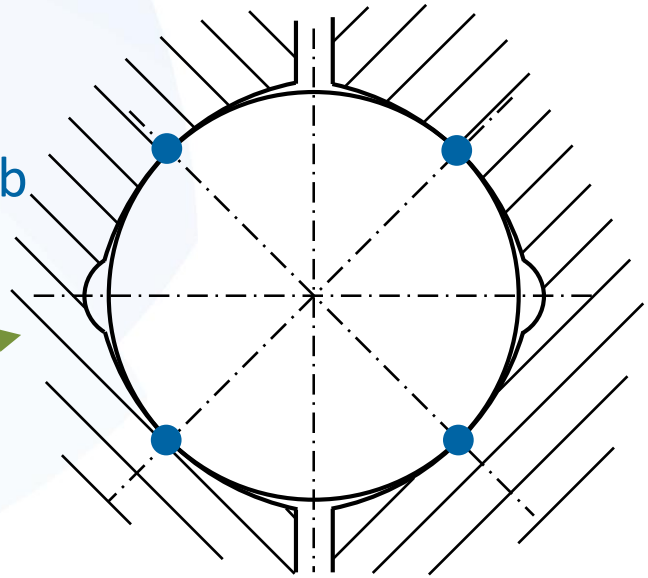
- **Sensor systems**
  - Premesy: reliable pre-load control
  - BBG: blade bearing monitoring

Load situation in blade bearings

Bearings and geometries

- Up to now: one or two-rowed preloaded ball bearings (four-point bearings)
- Technical design with cage or spacers
- Raceways are induction hardened
- Pitched rings might have gears
- Bolt connection of rings with blade and hub

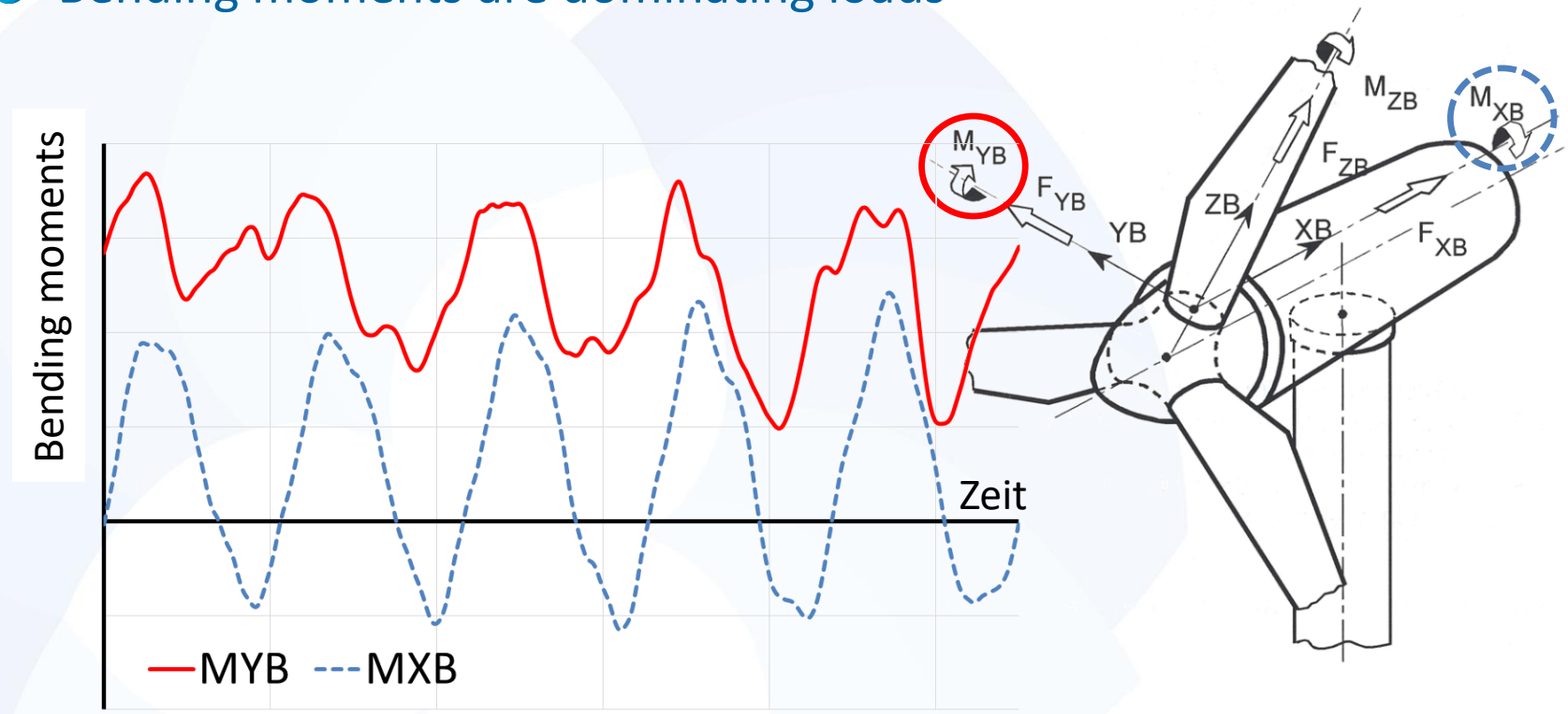




Load situation in blade bearings

Rotor loads

- Bending moments are dominating loads

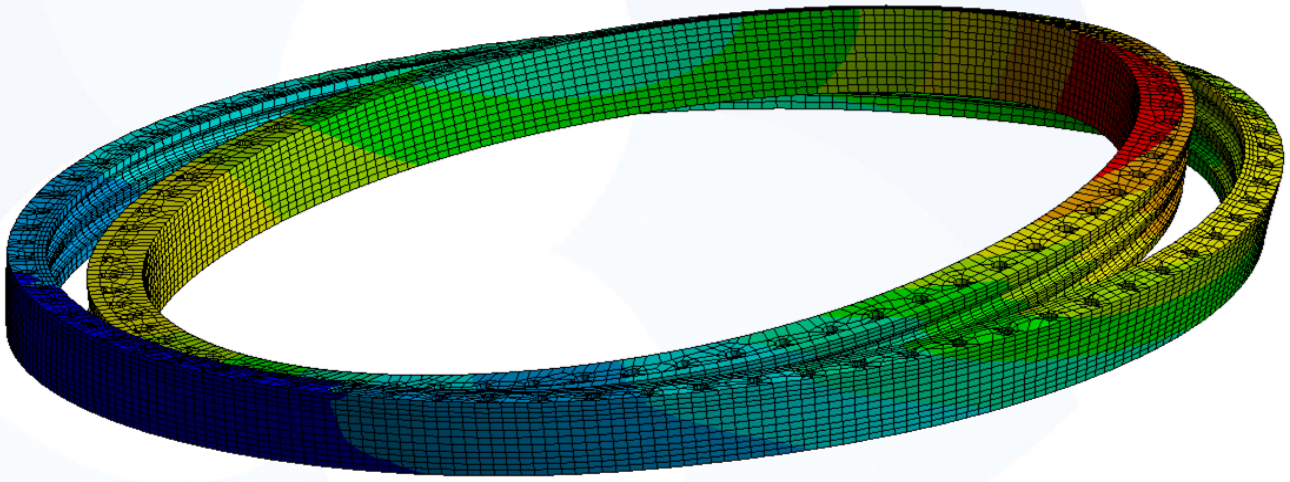


→ **High alternating bending moments with rotor frequency**

Load situation in blade bearings

Influences on bearing deformation

- Calculation of the system with hub, blade and bolts (only rings visualized)
- Deformation visualized in hundredfold enlargement



→ **Strong misalignment of the rings**

Ordinary Bearing Monitoring

Blade Bearing Examination

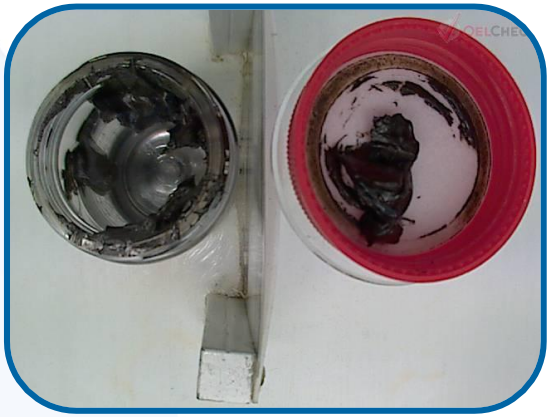
- Recognizable noises during pitching
- Delayed pitching
- Different pitch current
- Offline measurement of axial tilting clearance
- Grease samples
- Ultrasonic measurements

Ordinary Bearing Monitoring

Blade Bearing Examination

Grease sample

WEAR			
Eisen	Fe	mg/kg	23561
Chrom	Cr	mg/kg	623
Zinn	Sn	mg/kg	0
Aluminium	Al	mg/kg	43
Nickel	Ni	mg/kg	166
Kupfer	Cu	mg/kg	308
Blei	Pb	mg/kg	0
Mangan	Mn	mg/kg	1221
PQ-Index	-		40004
CONTAMINATION			
Silizium	Si	mg/kg	519
Kalium	K	mg/kg	25
Natrium	Na	mg/kg	116
Lithium	Li	mg/kg	1165
Titan	Ti	mg/kg	6
Vanadium	V	mg/kg	4
Wolfram	W	mg/kg	7955
Cadmium	Cd	mg/kg	64
Kobalt	Co	mg/kg	32
Wasser K. F.	ppm		156129



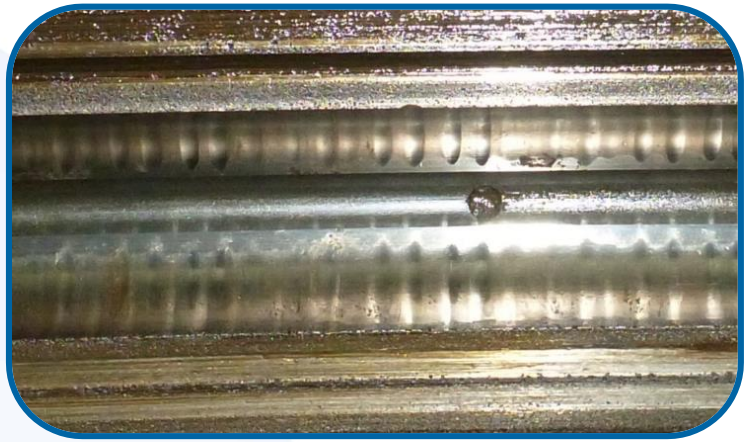
→ **Sample quality depends strongly on sample point**

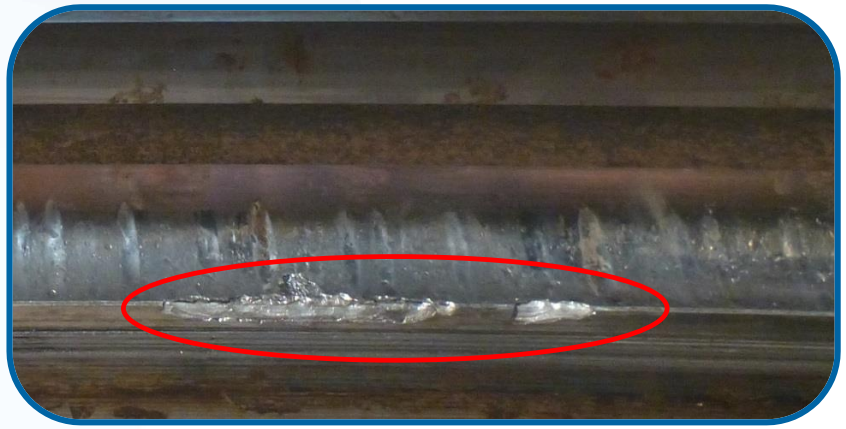
→ **Pollution not comparable with rotating bearings**

Damages During Operation

Possible damages

- False Brinelling
- Edge chipping
- Broken rolling elements
- Secondary damages due to overrun

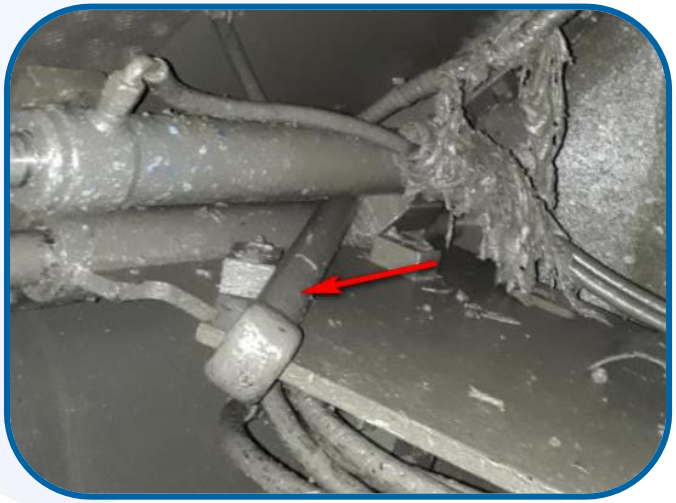


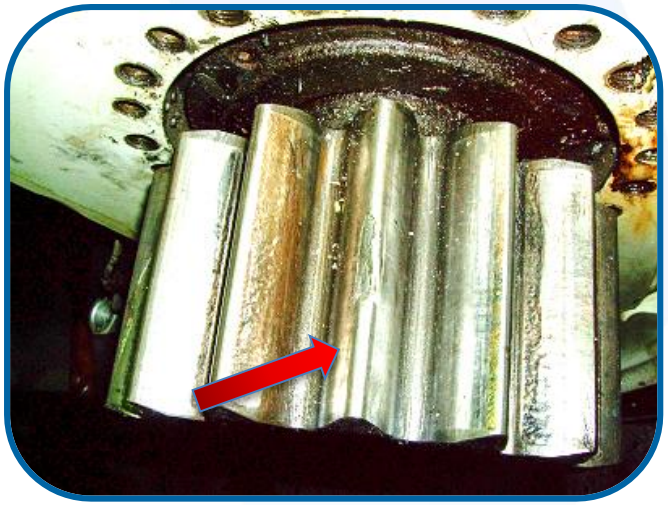


Damages During Operation

Possible resulting damages

- Damages on pitch adjustments
- Sealing damages
- Failure of connecting elements

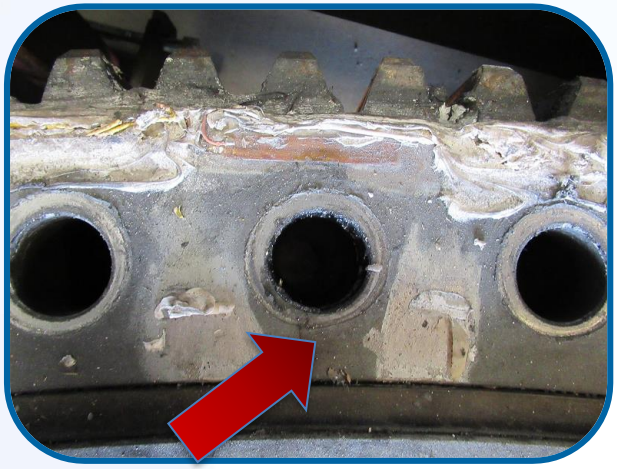




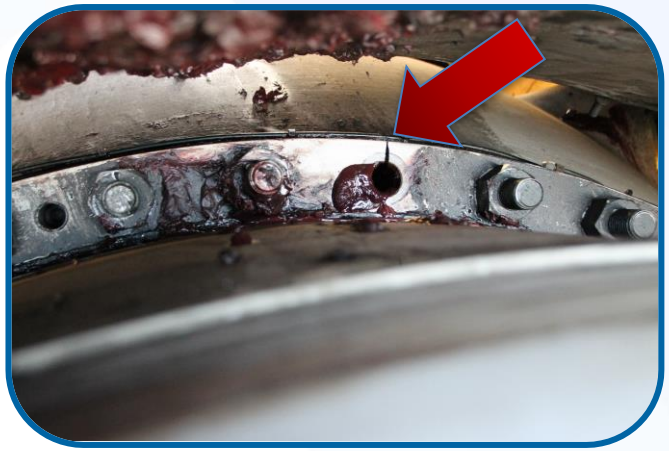
Damages During Operation

Blade Bearing Cracks

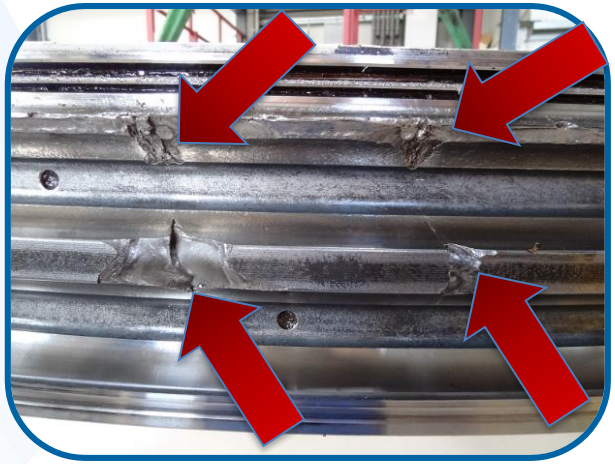
Outer ring,
(geared pitch)



Outer ring,
(hydraulic pitch)



Inner ring,
(geared pitch)



→ **Increasing number of ring cracks in field**

Damages During Operation

Blade Bearing Cracks

- 2.5MW turbine: Broken outer ring – working bolt connection

BBG - Blade Bearing Guard

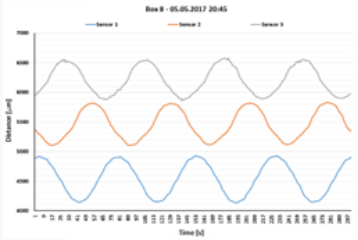
Monitoring Solution BBG

Measurements with at least one sensor per blade bearing

BBG Measurement

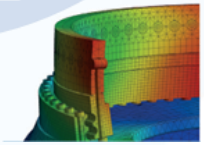
Data processing and automated monitoring

BBG Database



Analyses

Bearing assessment



Detailed failure evaluation and planning of replacement

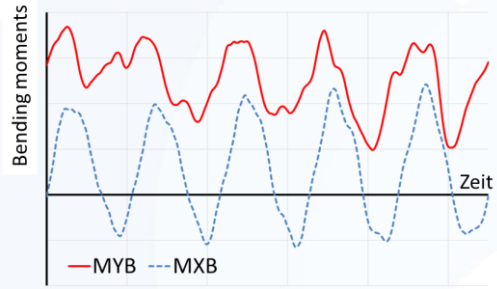
Documentation

Maintenance decision

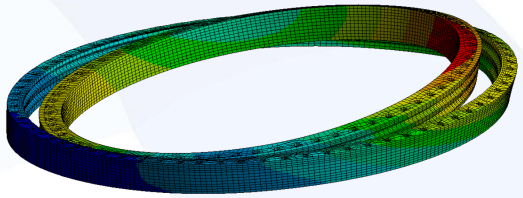
BBG - Blade Bearing Guard

Monitoring of changes in deformation

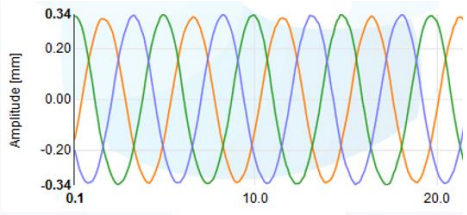
- Monitoring of load M_{XB} by measuring the deformation of the rings



Load simulation



Real deformation



BBG measurement

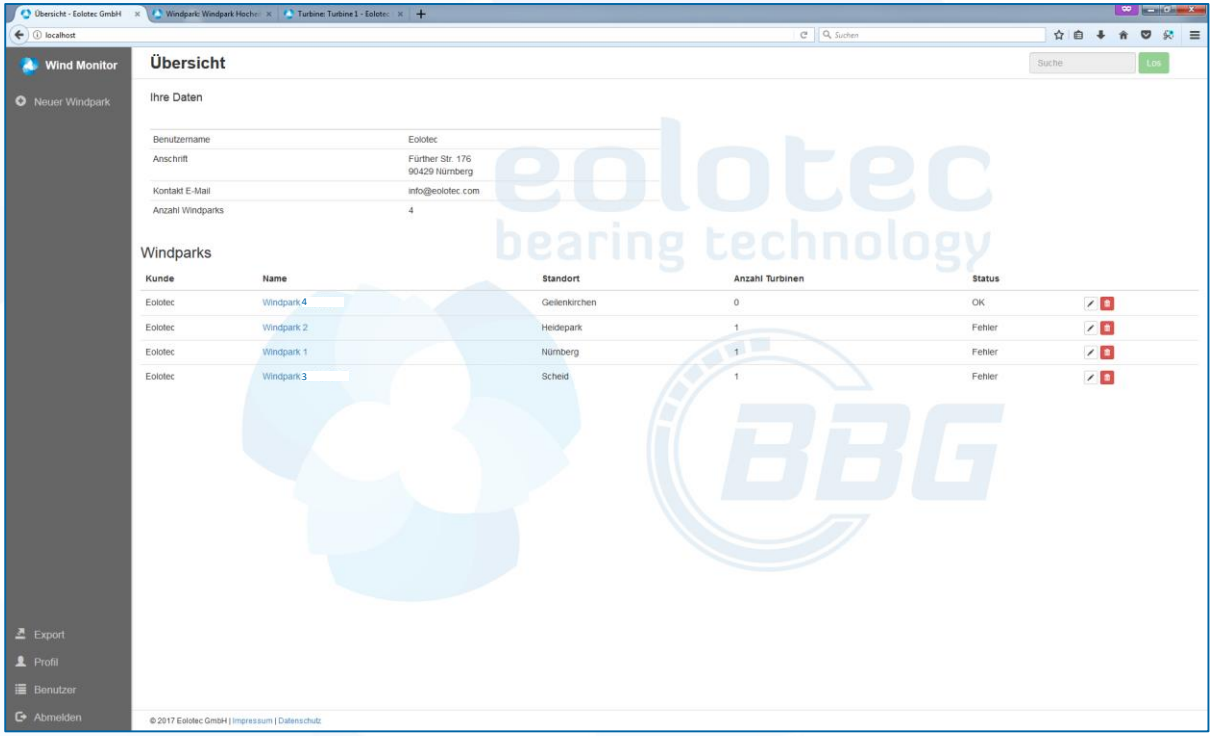
- Wear processes within the rings and the rolling elements lead to an increased deformation of the rings
- Ring cracks, ball breakage or outbreaks have direct influence on ring deformation

→ The continuous monitoring allows to detect the probable time of failure

BBG - Blade Bearing Guard

BBG User Platform

- An online platform displays the BBG measurements of all wind turbines
- Customer access to online platform



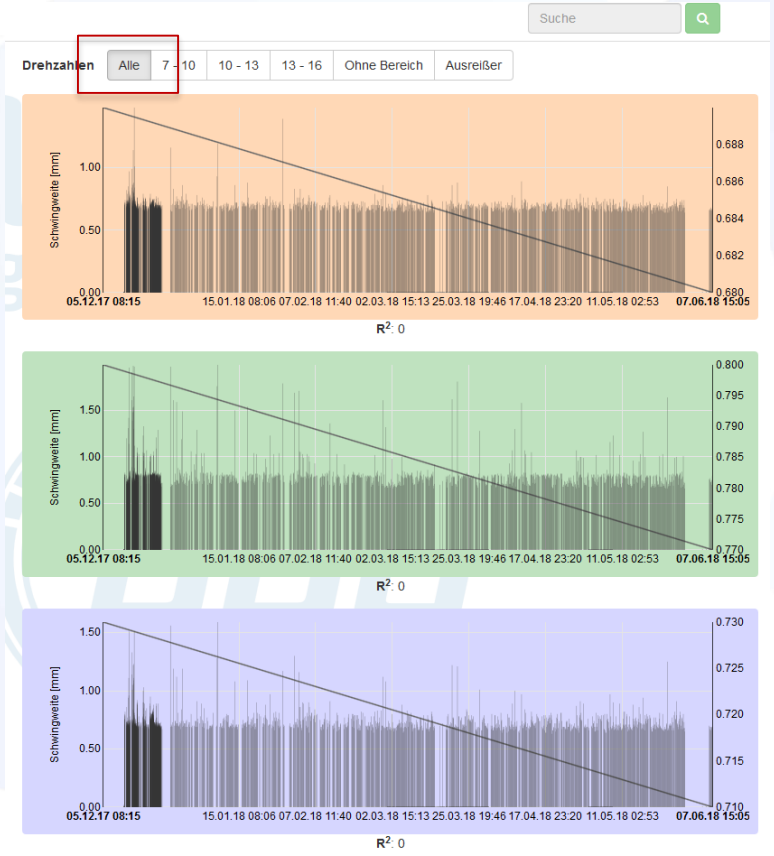
BBG - Blade Bearing Guard

Exemplary measurement on BBG-Platform

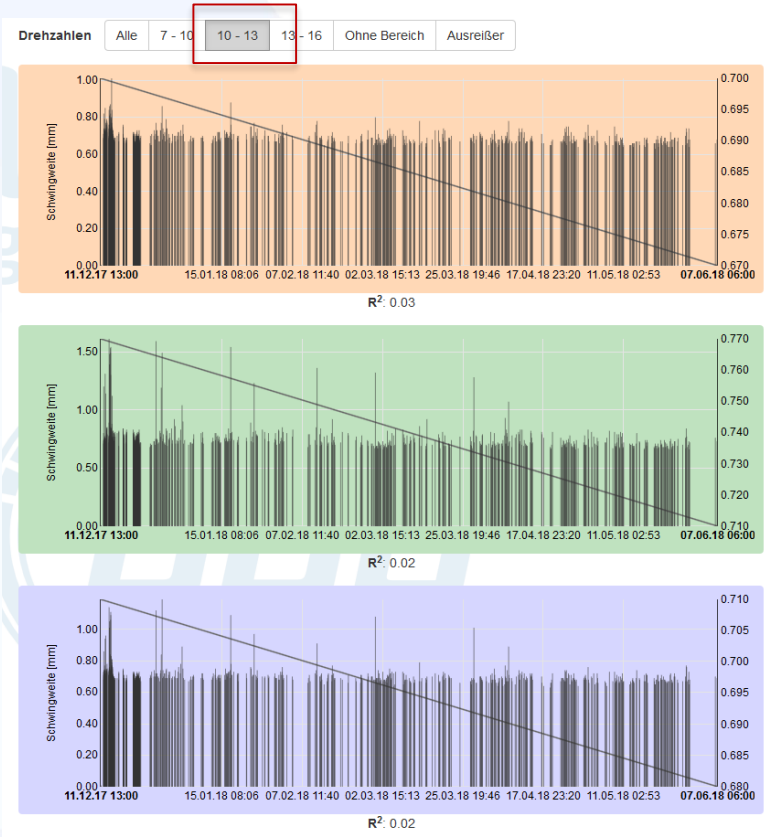
BBG - Blade Bearing Guard

Exemplary measurement on BBG-Platform

- Measurement of complete rpm range



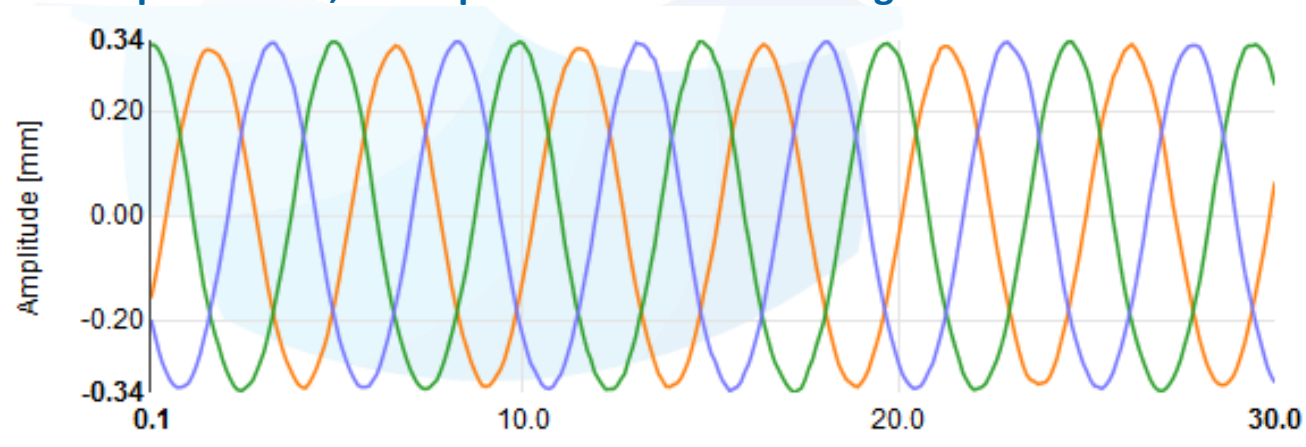
- Classified 10-13 rpm



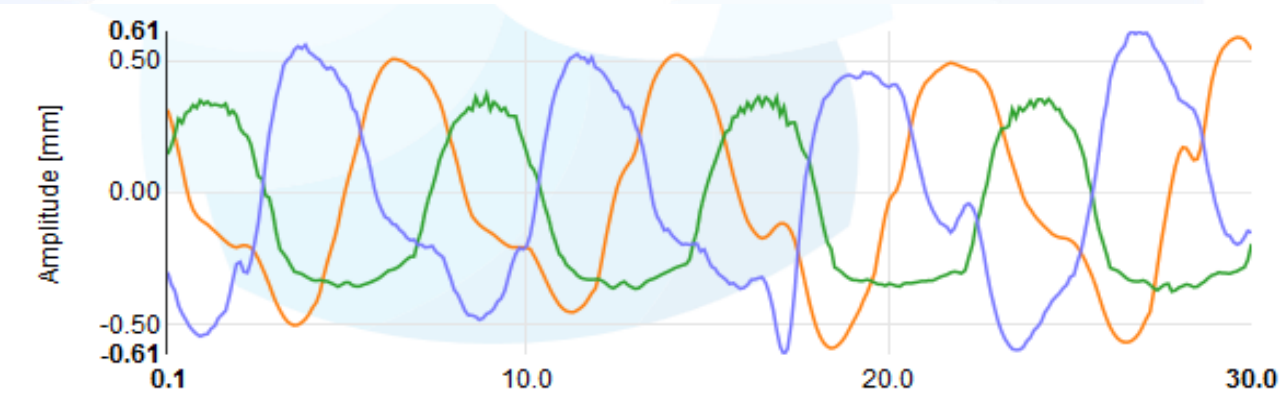
BBG - Blade Bearing Guard

Comparison of different measurements

Turbine in operation: 2,4 MW power class new bearings



Turbine in operation: 2,5MW power class with issues



BBG - Blade Bearing Guard

Currently installed on 8 different turbine types

Over 40 systems in field

- BBG Box monitors each single blade bearing
- Independent of controller or CMS
- Minimal power use
- No impact onto turbine structure
- Designed for rough conditions IP54
- Low data rate (< 100 kB/box)

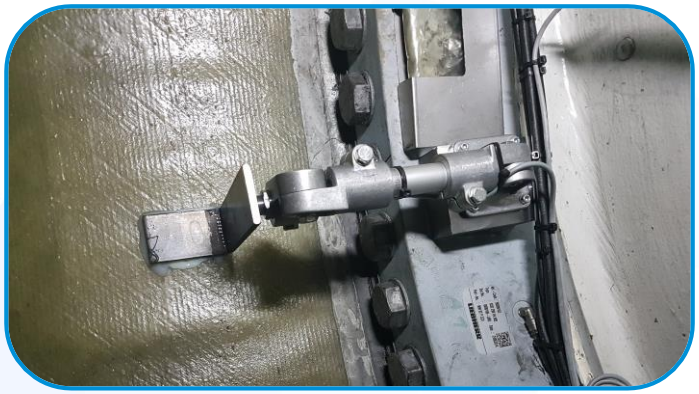
→ Adaptive assembly enables application in all common turbines

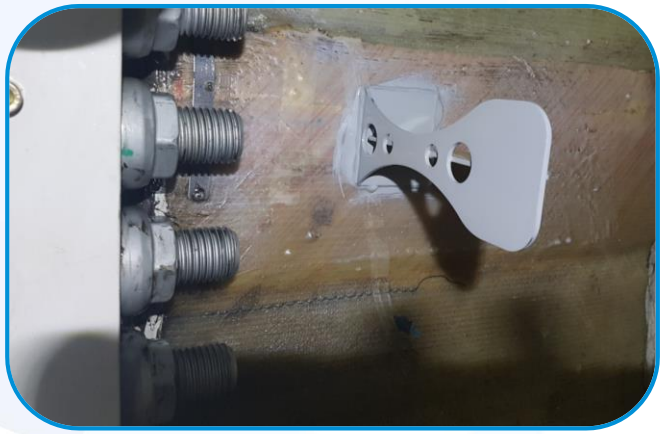
BBG - Blade Bearing Guard

BBG Boxes in different turbines

BBG - Blade Bearing Guard

Sensor installations (examples)





Conclusion

- BBG system provides reliable information to the current condition of blade bearings
- Due to the low slewing rate the damage progress is comparatively slow
- Measured deformation increases with growth of damage
- Appropriate measures can keep a pre-damaged bearing operational
- A potential exchange can be scheduled in advance
- Targeted monitoring by BBG makes further operation possible

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