Journal Bearings in Wind Turbine Gearboxes
extended investigations for reliability
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Overview

R&D Journal Bearings
Activities in 2015/2016, further investigations for reliability

Single Blade Installation
Installation: high torque @ very low speed

Wear Behavior CuSn12Ni2-GZ
RNT measurement

Performance of different Lubricants
Load capacity and friction behavior, used field oil

Field Performance JB gbx
4 years of operation - facts

Prototype Testing 8MW gbx
Noise and vibration behavior – roller vs journal bearings

Real Life Experiences
Status and forecast cumulative field experiences

What next?
Target, Motivation and Approach
R&D Journal Bearings – activities in 2015-2016

Motivation, Target Setting

- secure safe introduction of new technology
- fulfill new requirements
- investigation of special operation – non-operation modes

Approach

- investigation on single blade installation, high torque @ very low speeds
- load capacity and friction behavior for different lubricants, Striebeck-curves
- fretting during transportation / stand-still
- investigation of the low wear behavior by RNT measurement

Single blade installation

Load capacity different lubricants

Fretting („false brinelling“)

RNT – wear behavior bronze CuSn12Ni2-GZ

become fretting an issue during transportation, installation or standstill?
R&D Investigation: **Single Blade Installation**
Friction / Temperature Behavior during Installation

### Motivation, Target Setting
- fulfill customer specification
- need for installation of huge rotor blades
- system risk assessment

### Test Features SBI

![Image of test setup](image)

**test performance:**
- run-in bearing for several hours @ 12 MPa
- SBI test procedure with no additional oil supply, only wet surfaces
- **initial lubricated bearing test**
- specific load 20 MPa @ \( v = 0.00134 \text{ m/s} \)

### Swinging Cycles

- permanent contact of the functional surfaces during test procedure => worse case
- break time: no standstill of the shaft, dynamic rotation => worse case

### Friction Torque and Temperature

- friction increase during swing cycle and increase of friction torque during procedure (100% up to 140%)
- no significant temperature increase during swing cycle (delta 0.5 K)

### Conclusion

- no scuffing and no wear detectable during test procedure, 8 cycles
- low failure risk during SBI = 2 swing cycles
- swing cycles >> 10: scuffing wear may occur to dry contact pattern

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Motivation, Target Setting

- abrasive wear is very low
- geometrical wear measurement not suitable
- need for a high measurement accuracy
- wear life time calculation required

Test Features RNT

- radio-activation of the Cu in alloy
- counting the gamma radiation of the wear particles with high resolution
- resolution limit: 0.1 µg / h
- Mobil Gear SHC XMP 320
- no filtration, closed oil circuit

Findings:

- wear rate scale [ nm / km sliding distance ]
- normal operation: no wear, wear seen for high loads and low speeds
- repeat operation (yellow bars) with less wear as before (blue bars)

Conclusion:

- approx. cumulative wear over 20 years of operation less than 4-8 µm, „almost no wear“, no influence on cleanness and geometry
Motivation, Target Setting

- different lubricants are released
- investigation of all lubricants
- are there any differences in load capacity and friction behavior?

Test Features RNT

Test performance:
- perform comparable Striebeck-curves
- different load levels 10 MPa -55 MPa
- friction torque measured during operation
- 4 different lubricants
- 3 years old field oil, including particles

friction torque and temperature:
- differences in friction and temperature levels determined on high load levels, no differences below 20 MPa
- run-in behavior and transition speed equal for all brands

Conclusion:
- all lubricants with a high load capacity
- Castrol brands slightly better than Mobil brands in load capacity
- transition speed differences seen on high loads, p > 40 MPa
Motivation, Target Setting

- different lubricants are released
- investigation of all lubricants
- are there any differences in load capacity and friction behavior?

Test Features RNT

- \( F_{\text{max}} = 216 \text{ kN} \)
- \( D = 120 \text{ mm} \)
- \( P_{\text{max}} = 60 \text{ MPa} \) (B/D = 0.25)
- \( v_{\text{max}} = 3.6 \text{ m/s} \) (n = 580 rpm)

Test performance:
- perform comparable Strubeck-curves
- different load levels \( 10 \text{ MPa} - 55 \text{ MPa} \)
- friction torque measured during operation
- 4 different lubricants
- 3 years old field oil, including particles
- oil cleanness acc. DIN ISO 4406: 16/14/10

friction torque and temperature:
- slightly increase of friction by using used oil, only high loads > 40 MPa
- no differences in temperature levels

Conclusion used field oil:
- better run-in behavior, polishing effects
- slightly wear (~ 2 µm) on bearings @ 55 MPa with an increase of surface roughness, not relevant for field operation \( p < 20 \text{ MPa} \)
- minimum of friction differences seen on high loads, \( p > 40 \text{ MPa} \)
Field Prototype: **Performance of the first Winergy gbx**  
4 Years of Operation – set up

**Motivation, Target Setting**

- After successful in-house test performance:
  - gain field experience with all relevant bearings, planetary wheel, helical stage
  - generate lessons learned items for next prototypes and pilot lots

**In House Test Performing**

- Gearbox shows good behavior on turbine
- Temperatures of bearings constant at rated power
- Oil samples without any wear particles
- No higher oil demand needed
- Design based on serial design, plug & play for serial OEM turbines

**Prototype Features**

**PEAJ 4435,2 – Vestas V90 – 2 MW Turbine**

- one planetary stage, two helical stages
- excluding carrier bearings: all bearings are journal bearings
- bronze-tin and aluminum-tin alloys used
- specific load radial bearings: 11,5...21 MPa
- specific load thrust bearings: 1,5 ...2 MPa

Better noise behavior

Turbine inspections without any issues

Original OSS can be used

Original cooling capacity of turbine sufficient

Oil samples without any wear particles

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Prototype Testing: Performance of Journal Bearings
Noise and vibration behavior, 8MW gearbox

Test Configuration

Test performance:
- back-to-back test arrangement
- roller vs journal bearing gbx
- 14 MW gbx test bench

Test Features

Vibration measurement scan:
- triax accelerator sensors used
- different sensor position

Conclusion:
- better vibration behavior for JB gbx, expected on higher MOFT
Prototype Testing: **Performance of Journal Bearings**

**Noise and vibration behavior, 8MW gearbox**

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**Test Configuration**

**Test performance:**
- back-to-back test arrangement
- roller vs journal bearing gbx
- 14 MW gbx test bench

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**Test Features**

**Noise measurement:**
- acc. DIN ISO 9614/2, spot

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**Conclusion:**
- better noise behavior on JB gbx, expected after vibration scan
- @ rated power: JB gbx noise value -3 dB(A)
Real Life Experiences: Status and Forecast
What next?

Field Validation

Summery turbine prototypes and:
- special operation modes and non-operation modes of a wind turbine are uncritical
- bearing loads in the gbx are below critical levels << 55 MPa
- journal bearings decrease noise and vibration levels
- readiness level for 0-series / pilot lots achieved

What next?
- extend prototype field validation
- gaining for more statistical validation, increase amount of field gearboxes
- how to test and qualify journal bearings in wind turbine gearboxes
Thank you for your Attention!

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