Journal Bearings in Wind Turbine Gearboxes

extended investigations for reliability

HMI MDA Forum 2017, Hannover

Dr. Thomas Meyer – 26.04.2017

Overview

winergy

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 2015-2106**

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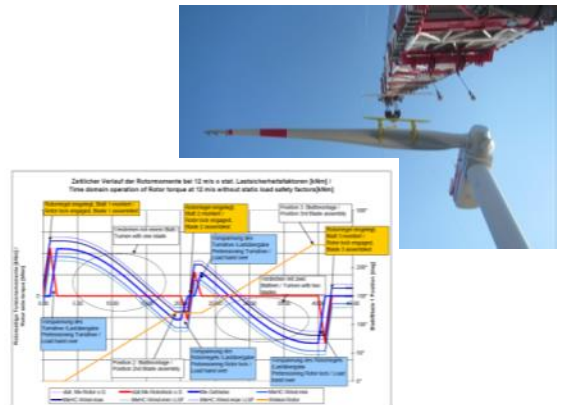
Motivation, Target Setting

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

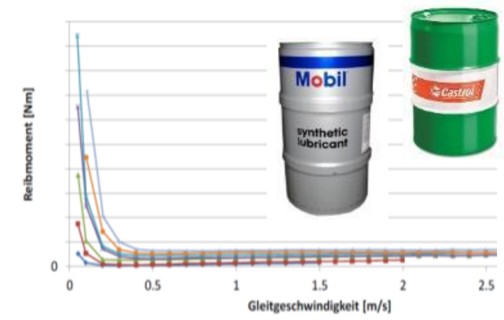
Approach

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

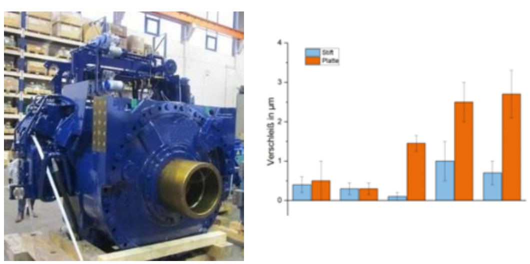
Single blade installation



Load capacity different lubricants

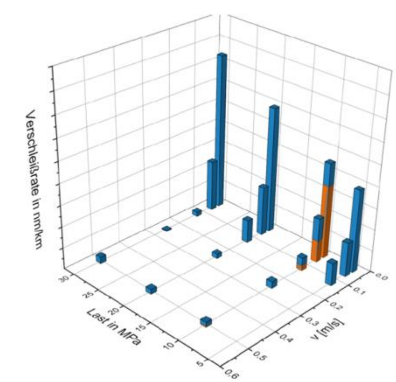


Fretting („false brinelling“)



become fretting an issue during transportation, installation or standstill?

RNT – wear behavior bronze CuSn12Ni2-GZ

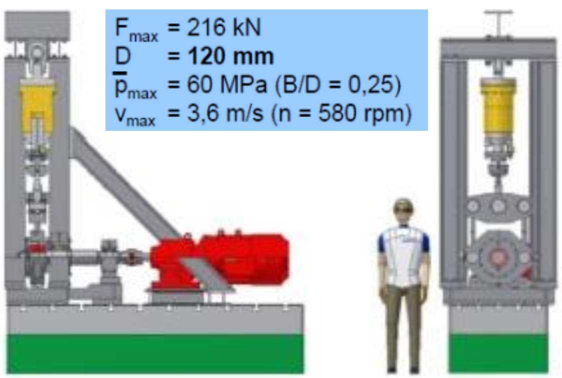


R&D Investigation: **Single Blade Installation**
Friction / Temperature Behavior during Installation

Motivation, Target Setting

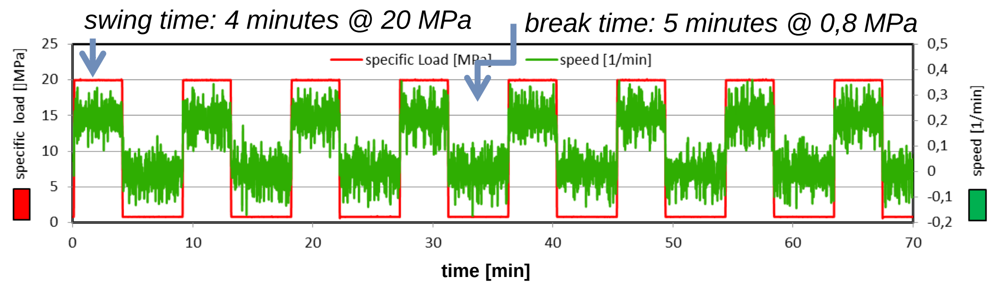
- *fulfill customer specification*
- *need for installation of huge rotor blades*
- *system risk assessment*

Test Features SBI



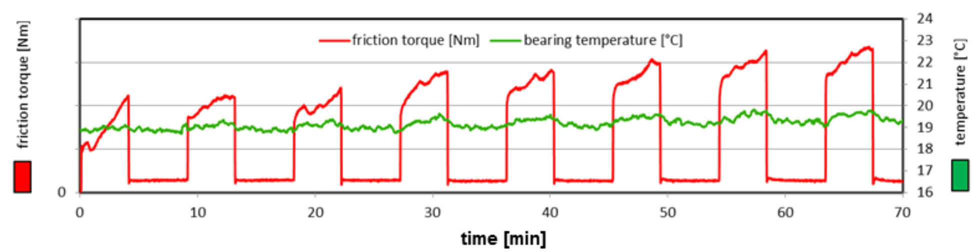
test performance:

- *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 m/s***



swing 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:

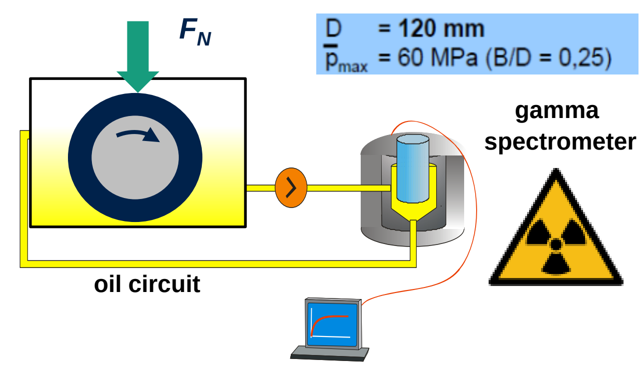
- *no scuffing and no wear detectable during test procedure, 8 cycles*
- *low failure risk during SBI = 2 swing cycles*
- *swing cycles >> 10: scuffing wear may occur to dry contact pattern*

R&D Investigation: **Wear Behavior - Characteristics**
RNT – Radionuclide Technology Wear Measurement

Motivation, Target Setting

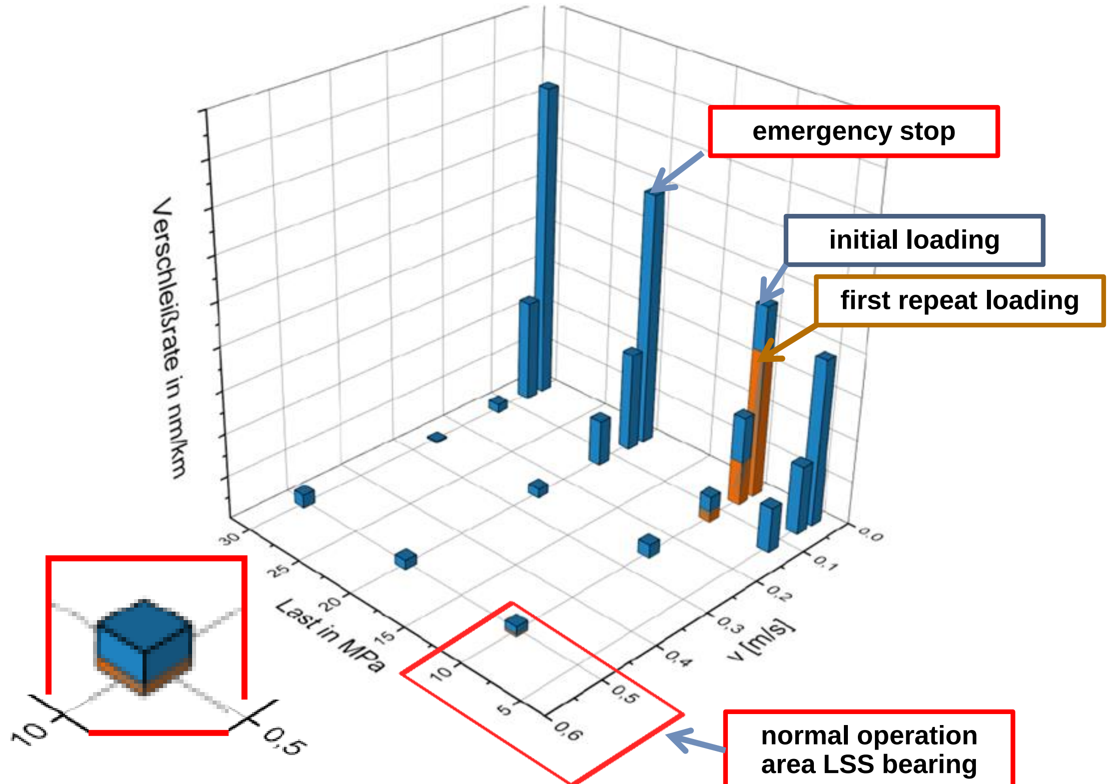
- *abrasive wear is very low*
- *geometrical wear measurement not suitable*
- *need for a high measurement accuracy*
- *wear life time calculation required*

Test Features RNT



Test performance:

- *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**:*

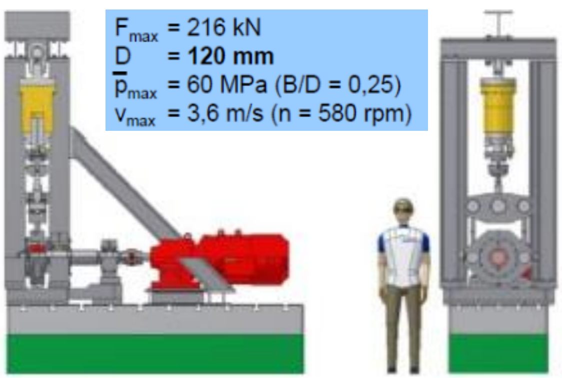
- *approx. cumulative wear over 20 years of operation less than 4-8 µm, „almost no wear“, no influence on cleanness and geometry*

R&D Investigation: **Performance of different lubricants**
Load Capacity and Friction Behavior

Motivation, Target Setting

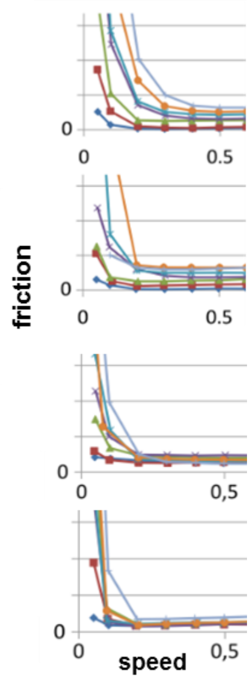
- *different lubricants are released*
- *investigation of all lubricants*
- *are there any differences in load capacity and friction behavior?*

Test Features RNT



Test performance:

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



Mobil Gear SHC XMP 320

friction ↗ — high load friction: ↘
transition speed → — run-in behavior: →

Mobil Gear XMP 320 WT

friction ↗ — high load friction: ↘
transition speed ↗ — run-in behavior: →

Castrol Synthetic X320

friction ↗ — high load friction: →
transition speed → — run-in behavior: ↗

Castrol Synthetic X320 WTO

friction ↗ — high load friction: →
transition speed: ↗ — run-in behavior: ↗

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**:*

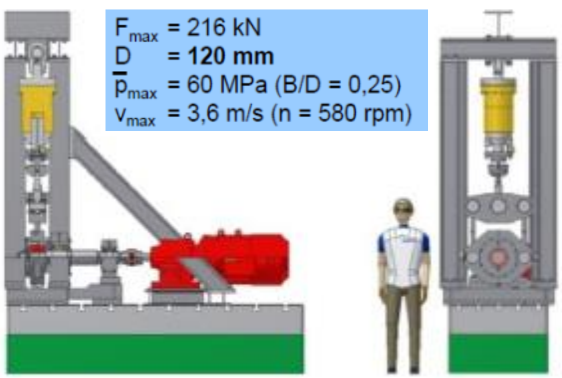
- *all lubricants with a high load capacity*
- *Castrol brands slightly better than Mobil brands in load capacity*
- *transition speed differences seen on high loads, p > 40 MPa*

R&D Investigation: **Performance of different lubricants**
Load Capacity and Friction Behavior, used field oil

Motivation, Target Setting

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

Test Features RNT



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- *perform comparable Stribeck-curves*
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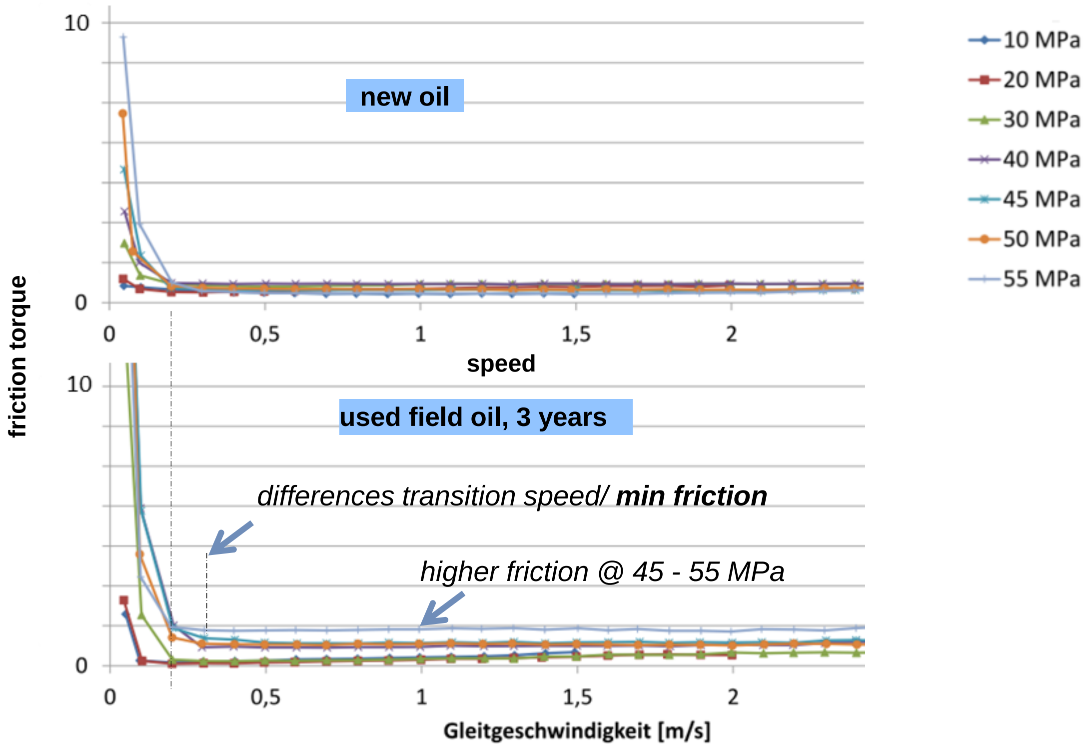
oil cleanness acc. DIN ISO 4406: 16/14/10



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 MPa)*
- *minimum of friction differences seen on high loads, p > 40 MPa*

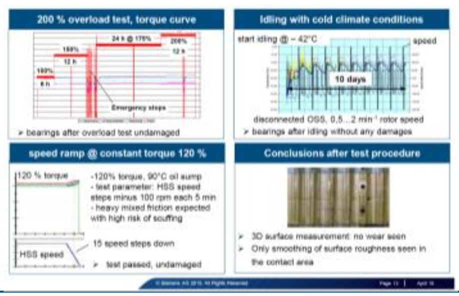
Field Prototype: **Performance of the first Winergy gbx**
4 Years of Operation – set up

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*

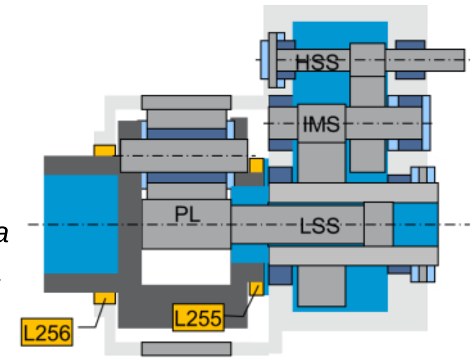
In House Test Performing

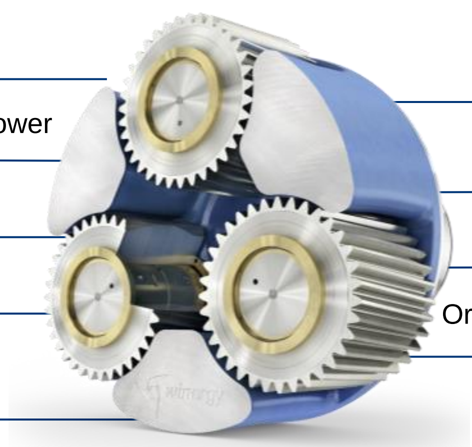


Prototype Features

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*





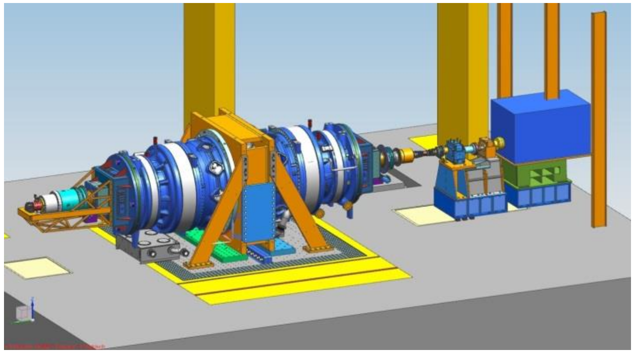
- Gearbox shows good behavior on turbine
- Temperatures of bearings constant at rated power
- Oil samples without any wear particles
- No higher oil demand needed
- Design based on serial design, plug & play for serial OEM turbines
- Better noise behavior
- Turbine inspections without any issues
- Original OSS can be used
- Original cooling capacity of turbine sufficient

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*



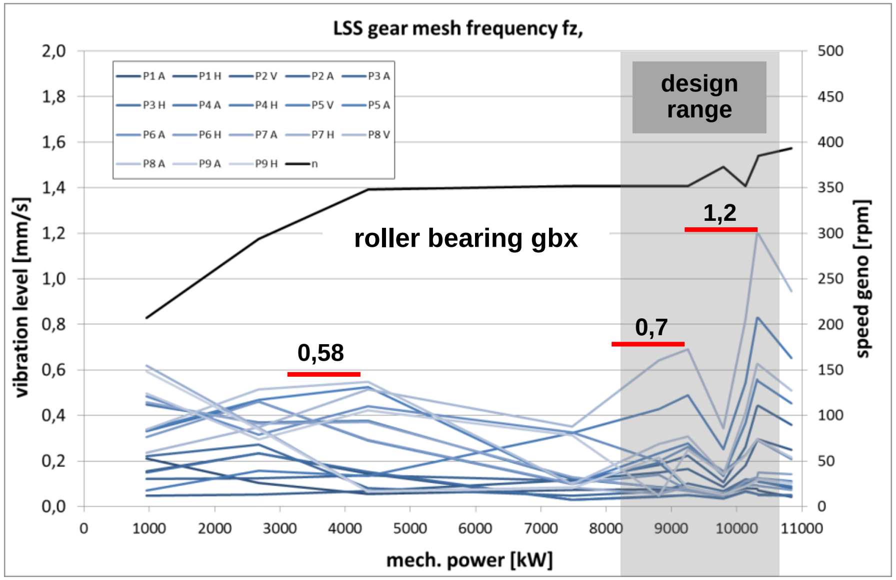
Test Features

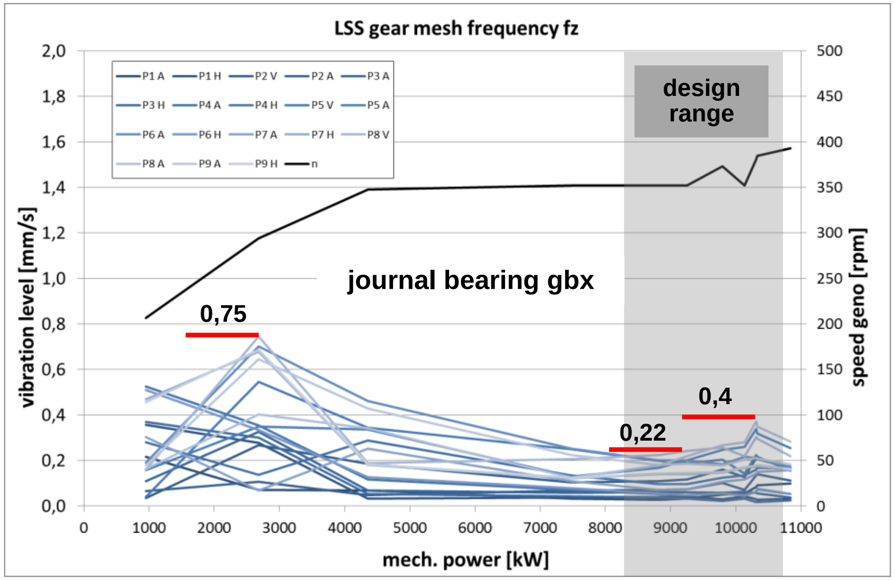
Vibration measurement scan:

- *triax accelerator sensors used*
- *different sensor position*

Conclusion*:*

- *better vibration behavior for JB gbx, expected on higher MOFT*





Prototype Testing: **Performance of Journal Bearings**
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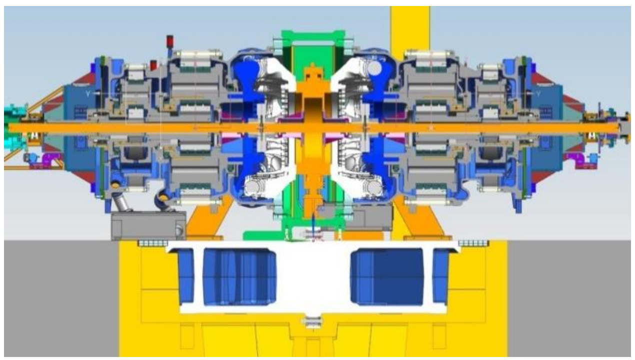


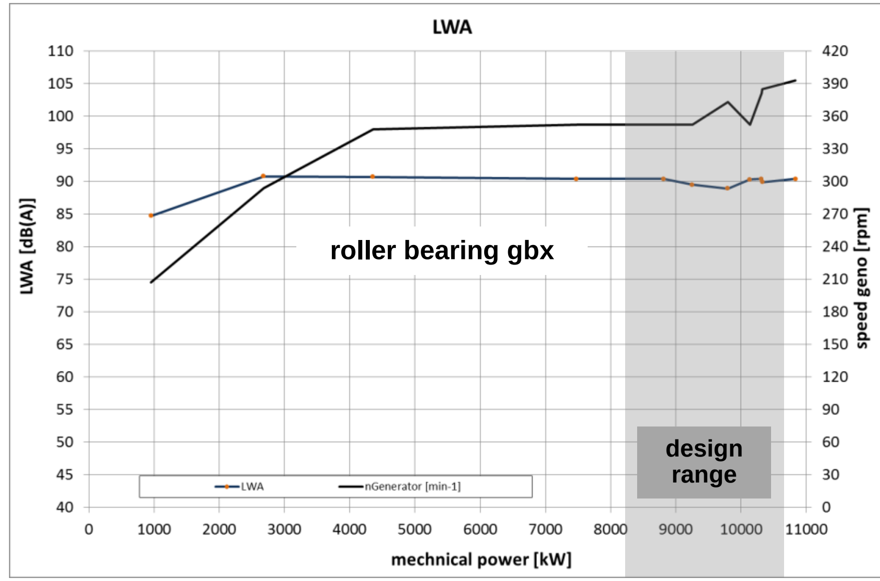
Test Features

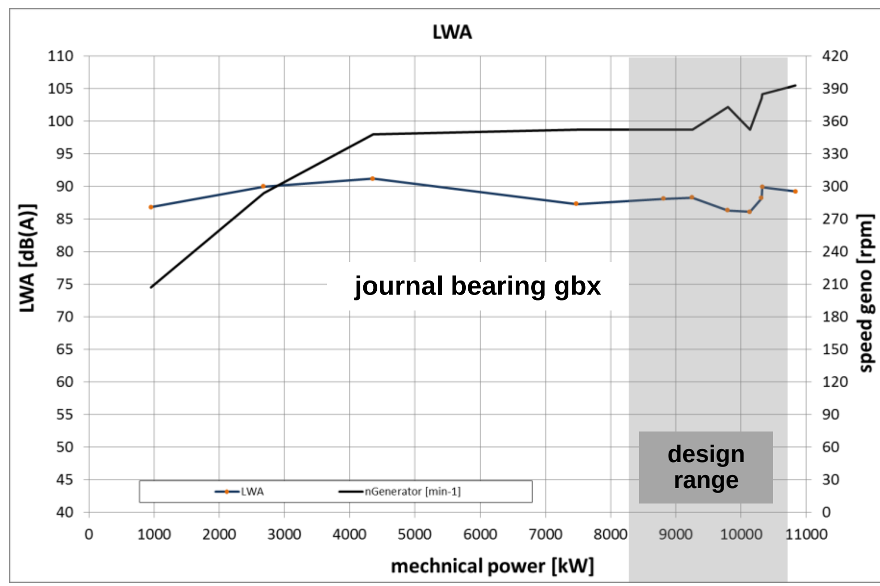
Noise measurement:

- *acc. DIN ISO 9614/2, spot*

***Conclusion**:*

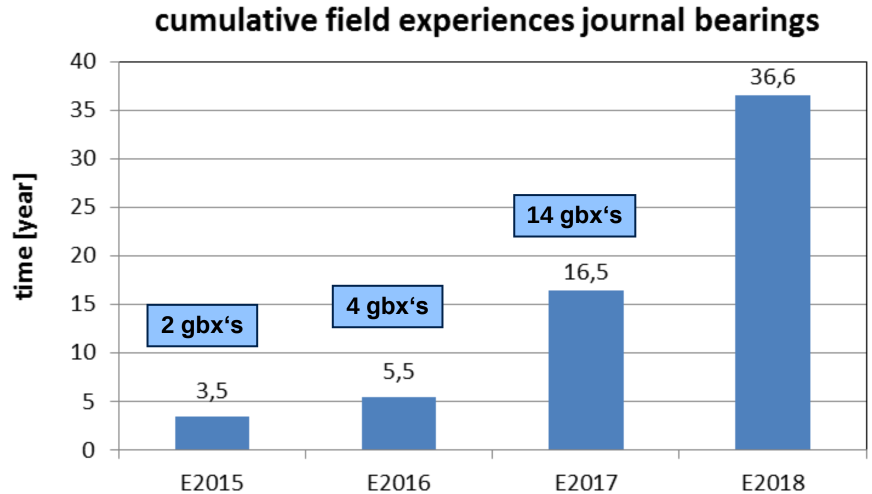
- *better noise behavior on JB gbx, expected after vibration scan*
- *@ rated power: JB gbx noise value -3 dB(A)*





Real Life Experiences: **Status** and **Forecast**
What next?

Field Validation



<u>Summery turbine prototypes and:</u>

- 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

<u>What next?</u>

- 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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