Allianz Global Corporate & Specialty SE

SECTION IV: RENEWABLE ENERGY

LESSONS LEARNED FROM DAMAGES OF MECHANICAL DRIVE TRAINS OF WIND TURBINES

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VGB Workshop
MATERIALS AND QUALITY ASSURANCE

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CONTENT TOPICS

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INTRODUCTION WIND ENERGY

WIND ENERGY IN GERMANY

Status by end of 2018

~ 30.500 installed turbines (96% onshore)

~ 59,3 GW installed power (89% onshore)

Typical turbine size

Onshore: 2-3 MW

Offshore: 5-6 MW

Power generation from wind energy 2018:

~ 112 TWh = 20% of German power generation

Utilization factor: 22%

Source: BWE, Dt. WindGuard, Fraunhofer IWES, BMWi, ZSW, FS-UNEP, TSN Emnid

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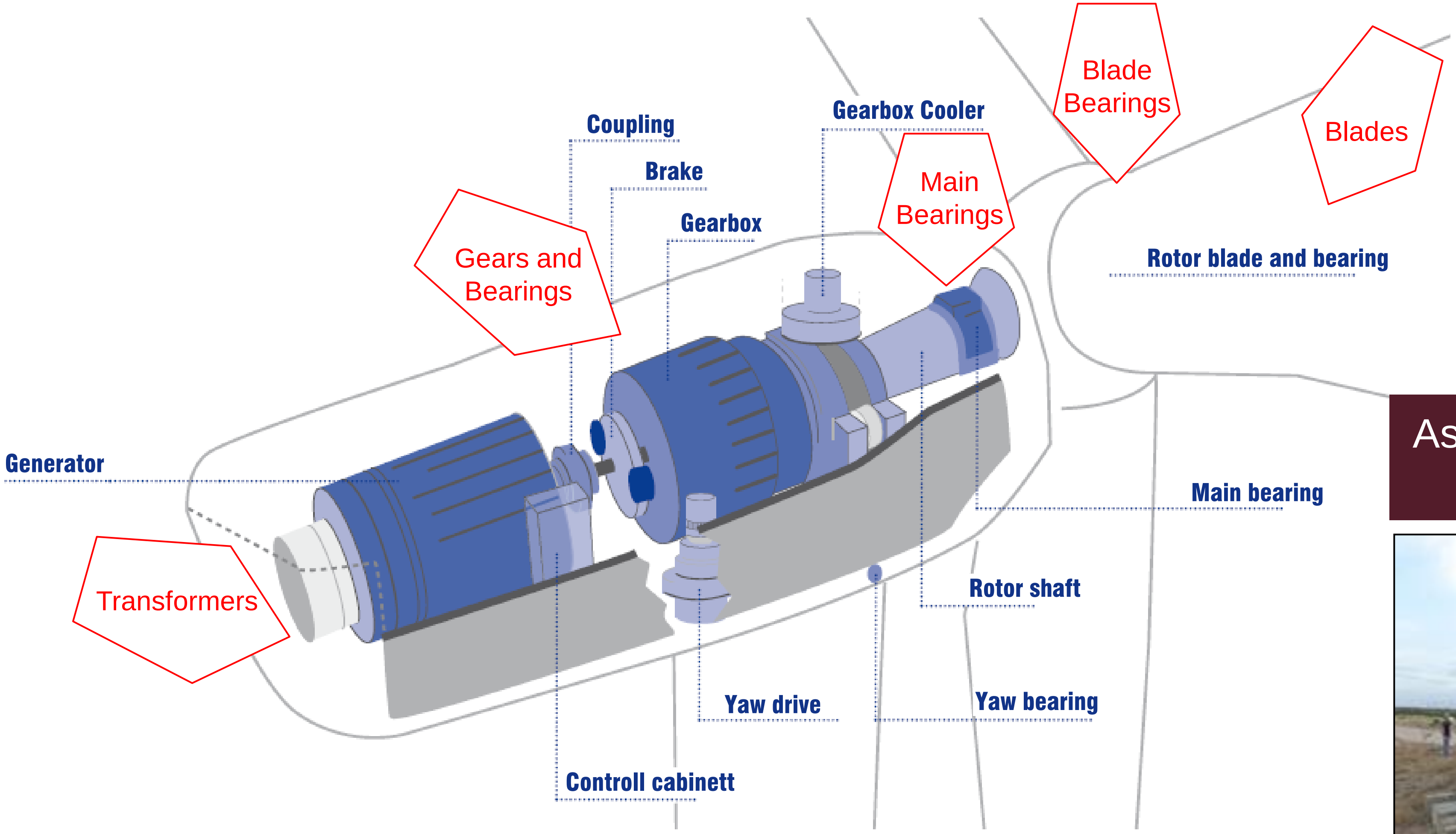
CURRENT MAIN DAMAGE AREAS

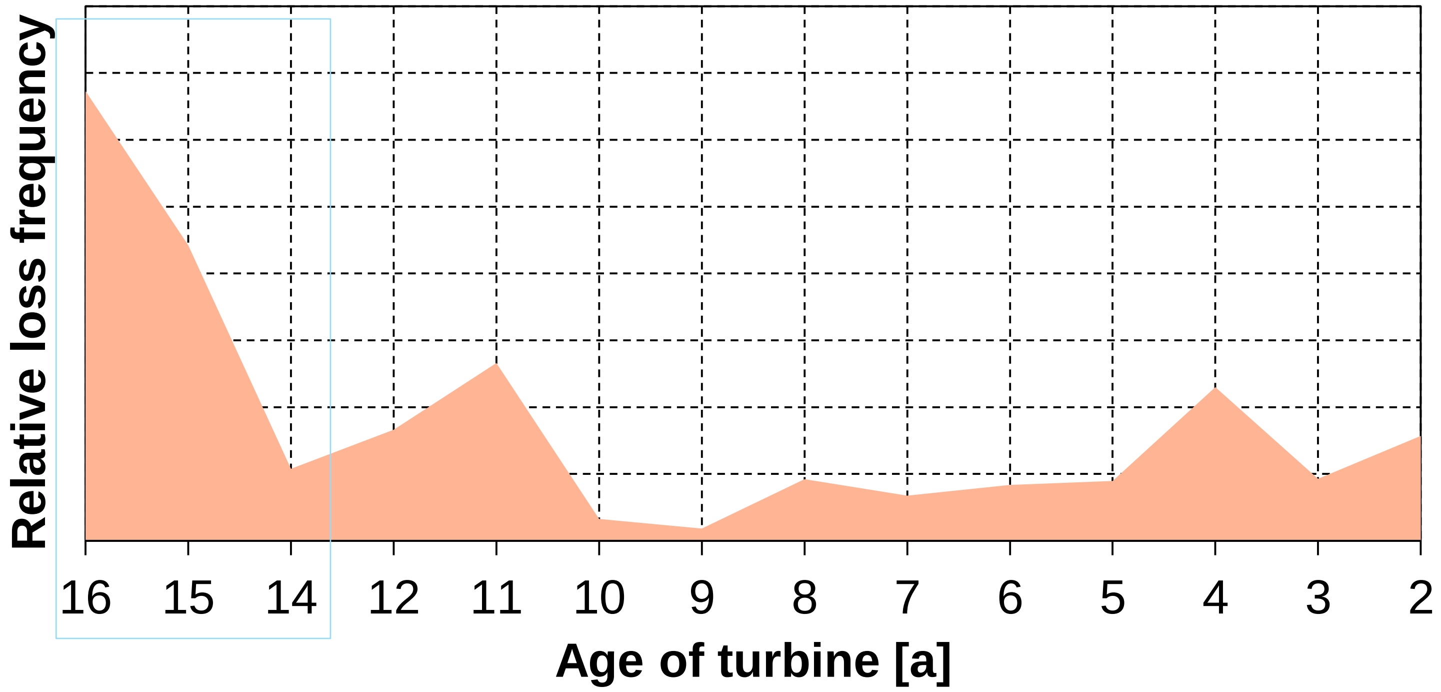
CURRENT MAIN DAMAGE AREAS

ACCORDING TO AGCS & AZT EXPERIENCE

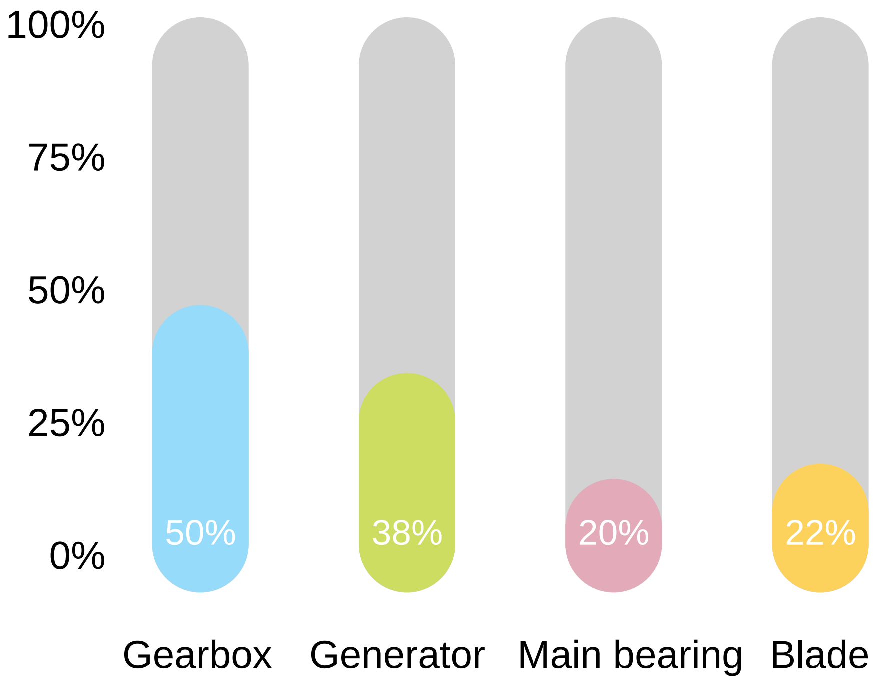


As well as total losses of entire WTs due to fire or collapse

WIND TURBINES AND AGE @ WIND ONSHORE



Relative frequency of losses at old age to losses over total operational time



- Older turbines show higher frequency for unscheduled maintenance
- Especially gearbox and generators failures at higher age
- Still there are many failures of major components, which happen earlier.

EXPERIENCE @ WIND OFFSHORE

- Long-term experience limited
- Damage severity offshore compared to onshore
- Relation of loss amount: Offshore : Onshore >10:1
- Overall seacable claims most significant cost driver

CURRENT MAIN DAMAGE AREAS OF MECHANICAL DRIVE TRAIN

- Blade Bearing
- Rotor Bearing
- Gearbox
- Generator Bearing

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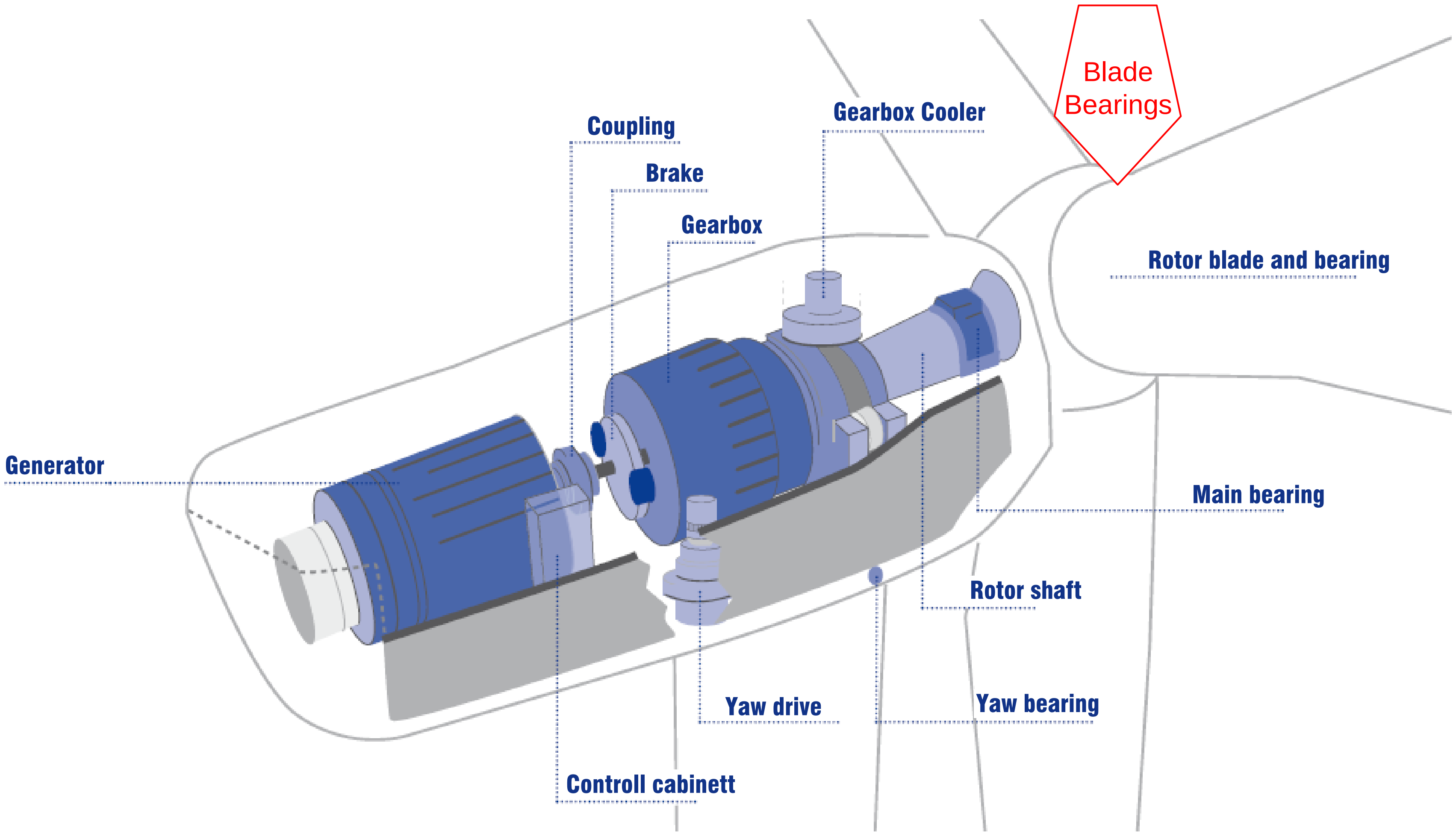
EXAMPLE 1 - BLADE BEARING



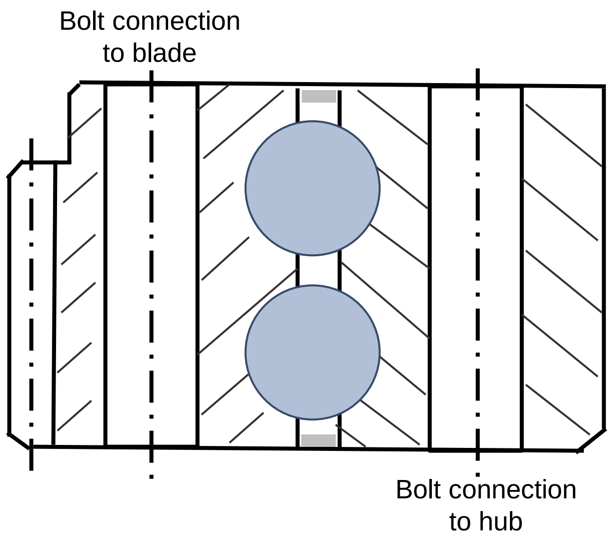
Blade Bearings

- located between hub and blades

- allow the pitching of the blades

Pitching is necessary for start and stoppage of the turbine.

Double row four point ball bearing



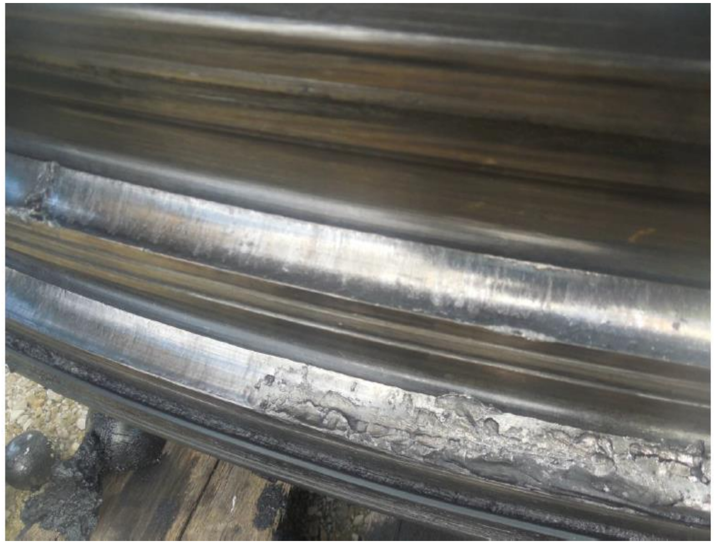
BLADE BEARINGS – CHALLENGES & THREATS

- High dynamic loads during standstill (lubrication)
- Small angular movements (lubrication)
- Continuous trend of enlarging rotor diameters (increased loads)
- Corrosive atmosphere (also for onshore application)
- Uneven stiffness of supporting structure (load shifting)
- Special features (cyclic pitch or individual pitch control)
- Improved methods for fatigue life time calculation still under development

SOME RECOGNIZED DAMAGE PATTERNS

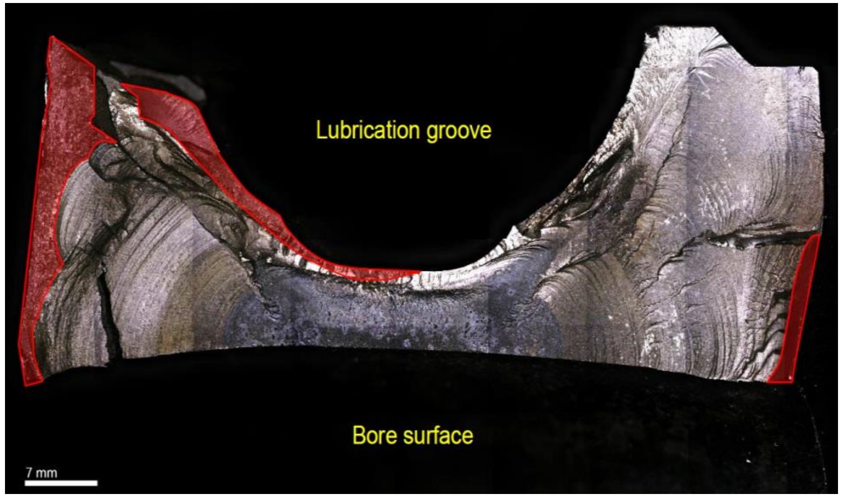
False Brinelling

Main contributors
- ➢ (Long) standstill periods of the bearing under dynamic loading
- ➢ Lubrication



Local spalling to the outer edge of the raceway

Main contributors
- ➢ High operational loads
- ➢ Cage design

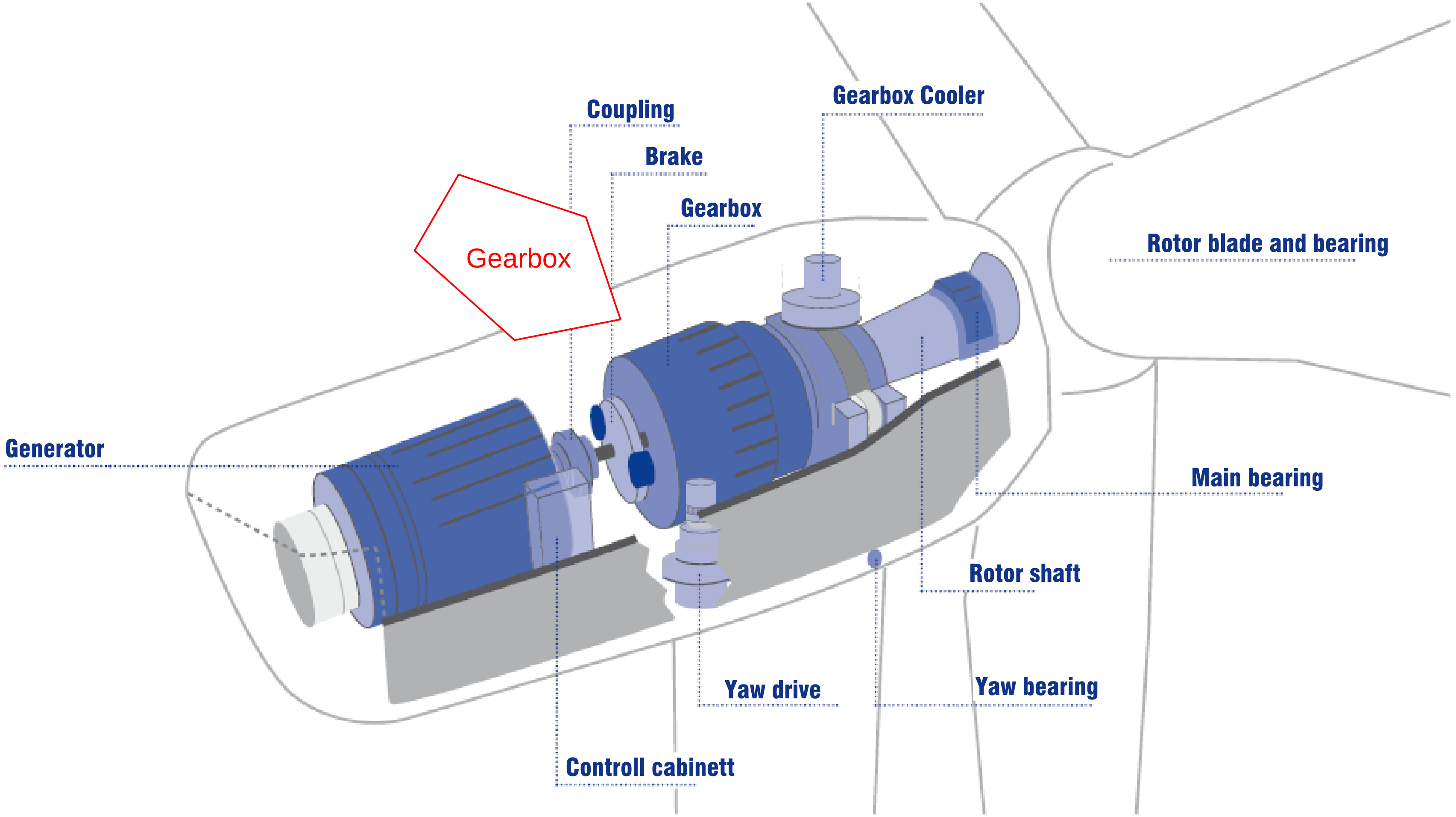


Stress corrosion cracking developed from bore surface

Main contributors
- ➢ Corrosion
- ➢ High static and dynamic loads

The number of blade bearings, which will be affected by a limited service life, might further increase.

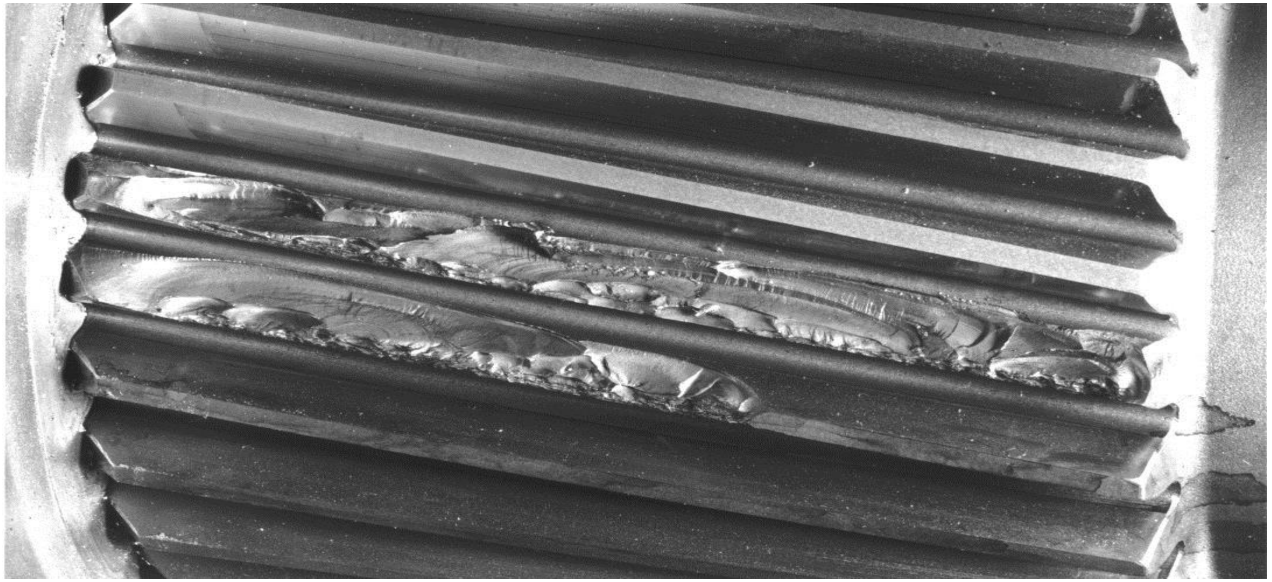
EXAMPLE 2 - GEARBOX



CURRENT DAMAGE EXPERIENCE ON GEARBOXES

Failure mode **Flank Breakage**

- known from turbogears used for gas / steam / water turbines for a long time
- crack start (CS) beneath hardening zone (HZ) from non-metallic inclusions
- fatigue crack growing under flank surface until breakage
- exchange and repair of gearbox



HZ = hardness zone

CURRENT DAMAGE EXPERIENCE ON GEARBOXES

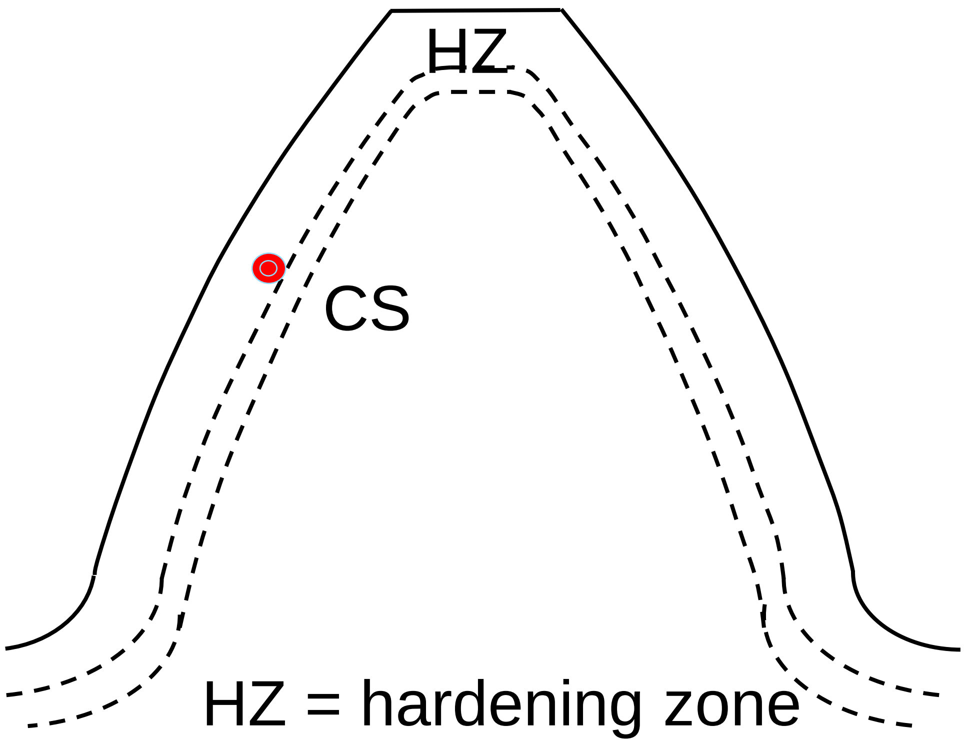
Contributors

- Sufficient case hardening depth
- Sufficient material quality (NMIs)
- Very high loads

- Check gears design acc. to new ISO/TS 6336-4:2019-01

To be ordered by customer!

- Tooth volume test

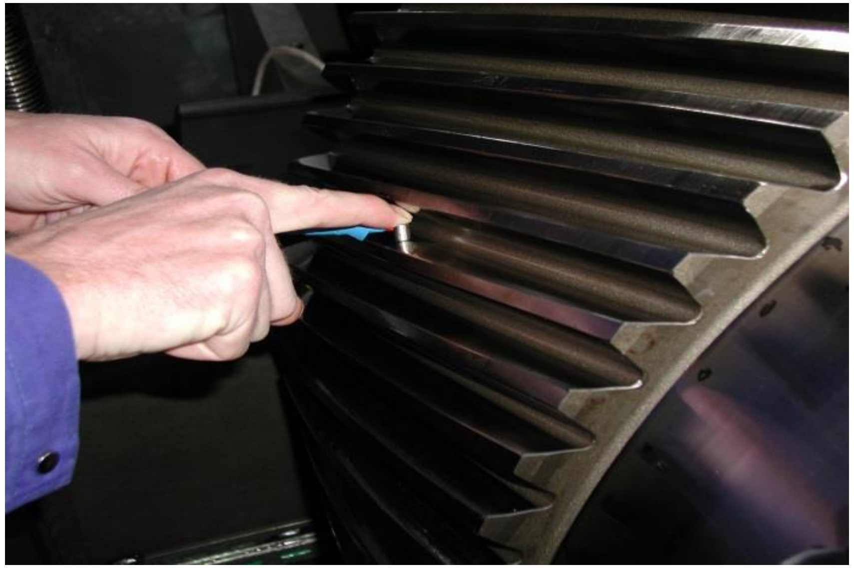


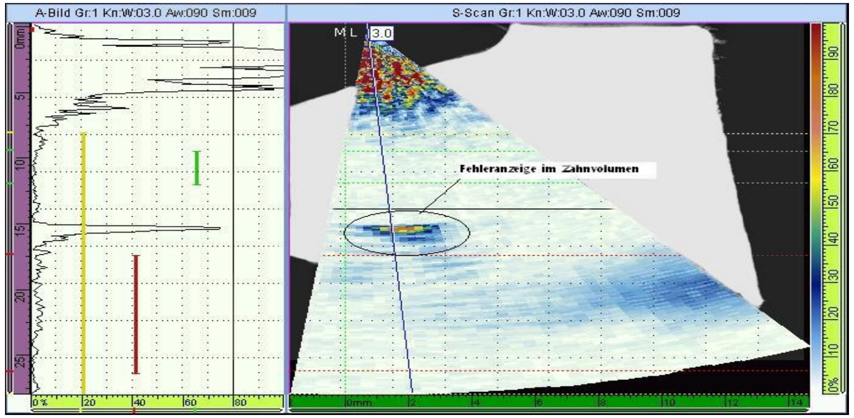
HZ = hardening zone
CS = Crack starter
HD = hardening depth
NMI = non-metallic inclusion

CURRENT DAMAGE EXPERIENCE ON GEARBOXES

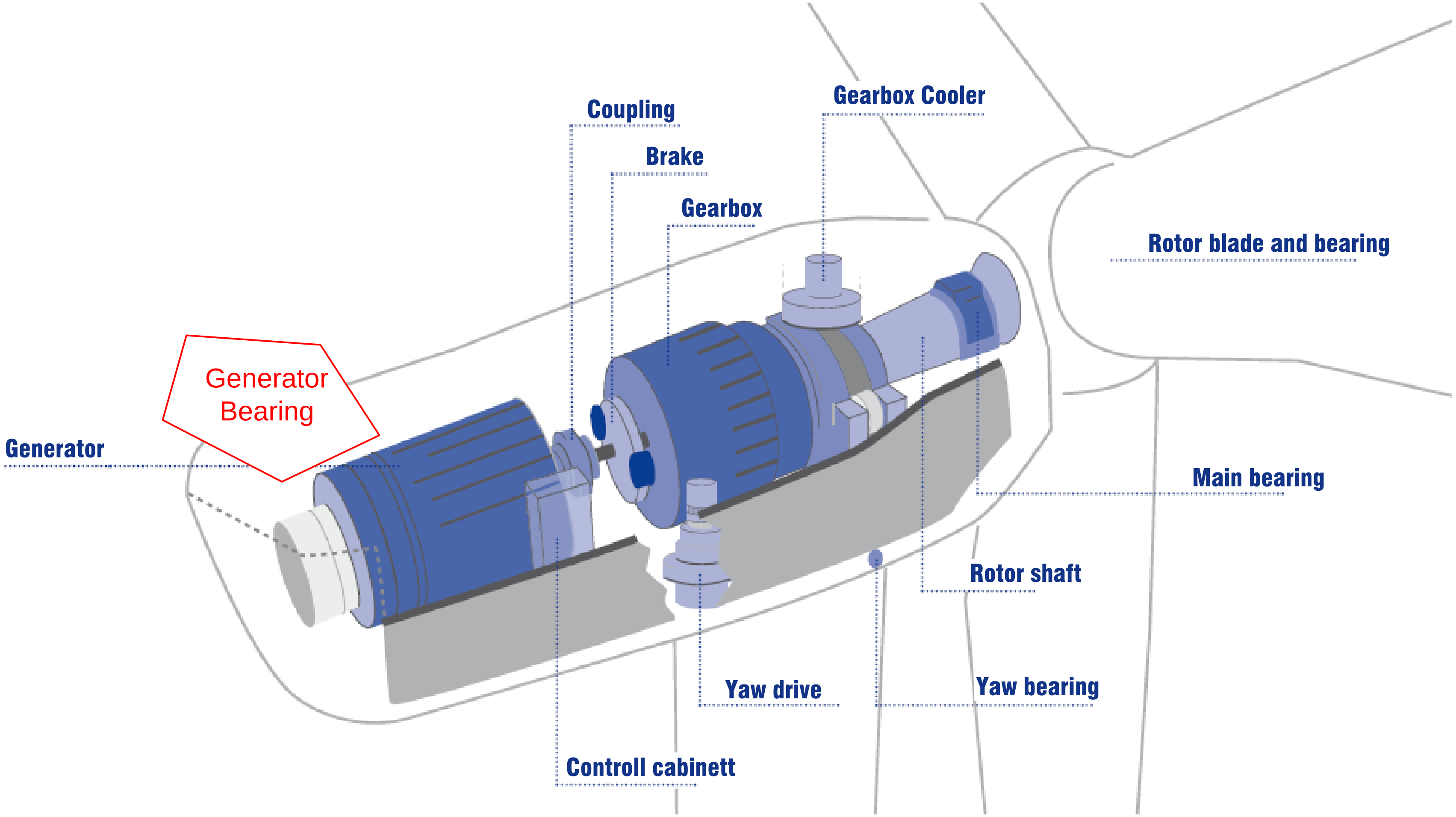
AZT tooth volume testing based on ultrasonic testing

- Detection of critical cracks in the tooth volume
- Crack development detectable by repeated testing
- Problem: direct access to gears is needed!
- Recommendation: Tooth volume test for prototype or during repair





EXAMPLE 3 - GENERATOR BEARING



WHITE ETCHING CRACKS

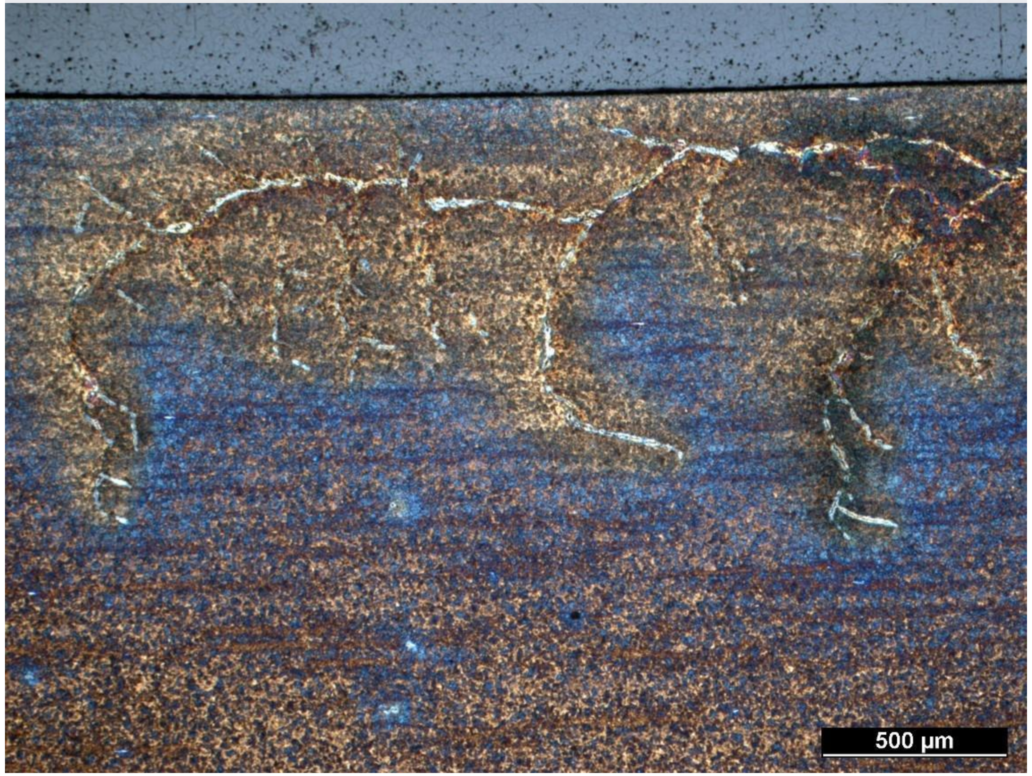
Failure Mode **WEC**

- Cracks and White Etching Areas (non-etching) in specimens of roller bearings after 5-10 % of rated lifetime
- Different damage mechanisms
- Possible contributors
  - Lubricant (additives)
  - Hydrogen
  - Electrical current
  - Slippage
  - Bearing material
  - Finishing
  - Vibrations
  - …

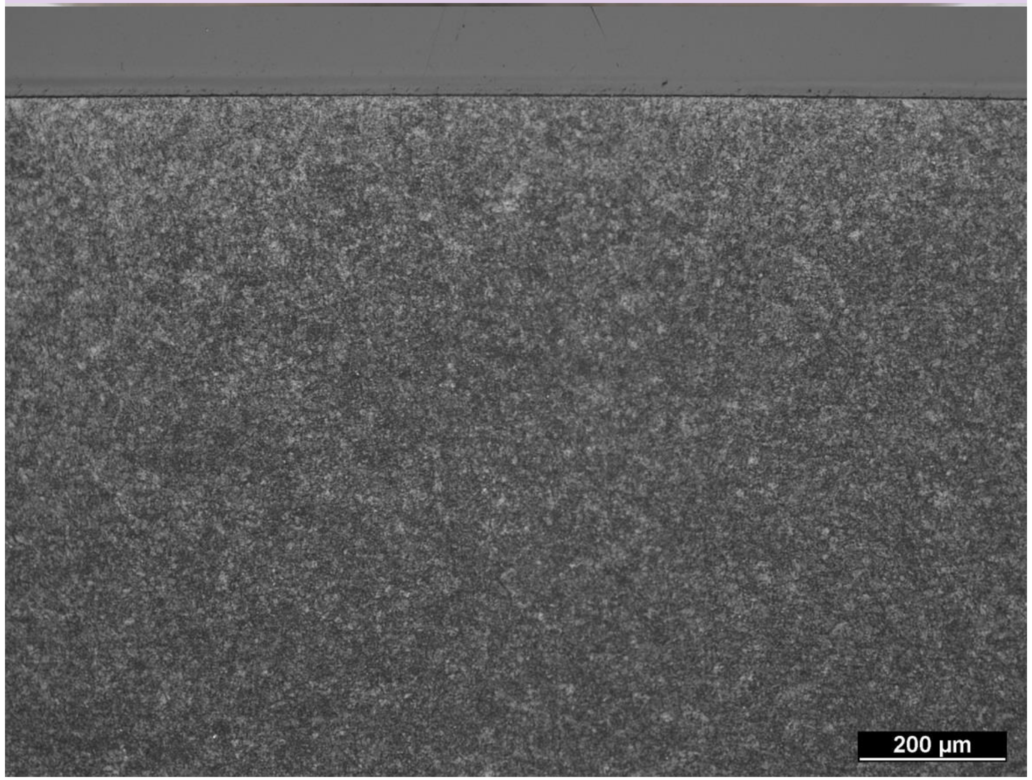
WEC is a complex failure mode, which is not understood to a satisfactory degree!

EXAMPLE 3 - GENERATOR BEARING

Generator bearing – electric current



Pump bearing – electric current



CONCLUSIONS

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CONCLUSIONS

Lessons learned @ Wind Onshore

Influences on component durability and life time are complex. A life time of 20 to 25 years for all main components (e.g. blade, blade bearing, main bearing, gearbox, transformer) cannot be realized so far.

Wind Offshore

Additional considerations like:

- Increase of full load hours
- Need for cost-efficient weight-optimized design
- Power upgrades with identical mechanical components
- Corretive measures are cost intensive (factor 10)

Claims Wind Onshore

- The determination of load conditions (also measurements), design methods, as well as test methods need to be further developed.
- A high material/ manufacturing quality is also needed for larger components.
- Regular visual inspection, endoscopy, oil analysis, continuous analysis of CMS and SCADA is important to detect deterioration in early phase.

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