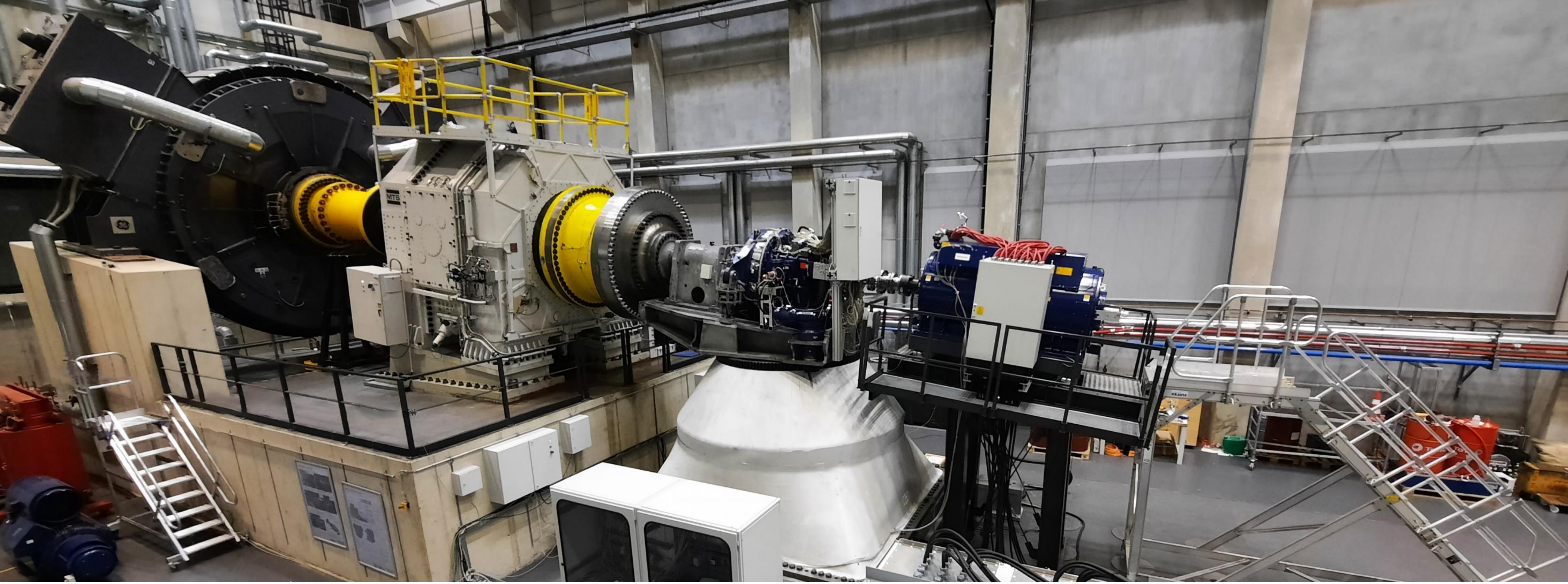


Development of a Methodology for a Gearbox Robustness Test

for slip-induced bearing damage and ring creep.

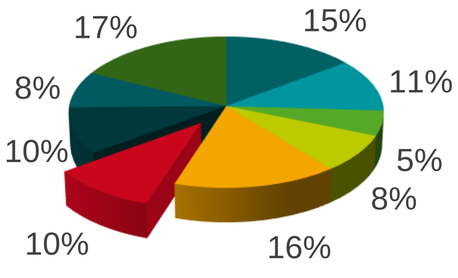
Jonas Gnauert, Alexander Krause, Georg Jacobs, Dennis Bosse

Aachen, 19-21.02.2021

CWD Chair for Wind Power Drives
RWTH AACHEN UNIVERSITY

Design process and testing according to [IEC 61400-4]
Bearings in wind turbine gearboxes

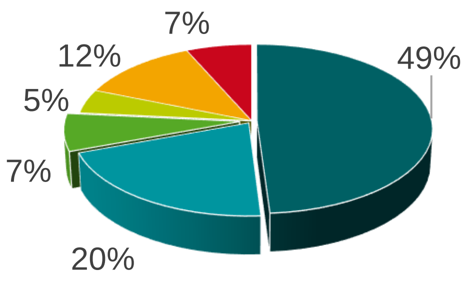
Share of downtime



[Faul 2011]

- Electrical System
- Electronic Control
- Hydraulic System
- Yaw System
- Rotor Hub/Blades
- Gearbox
- Generator
- Support & Housing
- Other

Share of gearbox failure



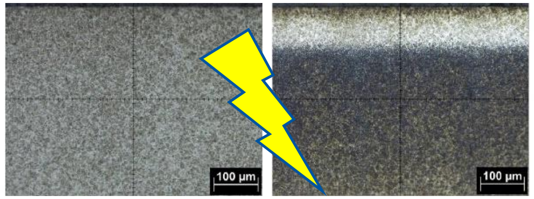
[Sheng 2016]

- HSS bearing
- IMS bearing
- Planetary gear bearing
- Planetary gear toothing
- Spur gears
- Other

Types of failure observed (ISO 15243 - extract):

- Fatigue starting below the surface (e.g. pitting and rehardening)

[Schaeffler 2000]

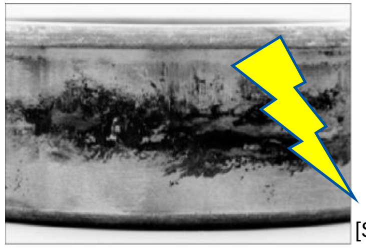


[vH15]

- Adhesive wear (smearing)

[NSK 2009]

- Fretting corrosion (micro movements e.g. due to ring creep)



[Schaeffler 2000]

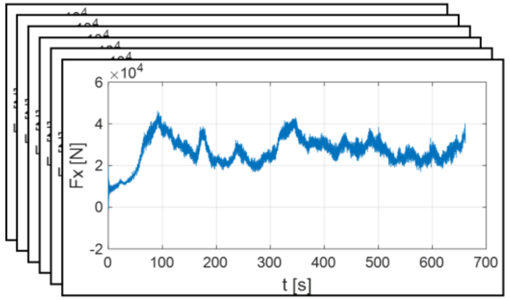
No standard method for testing nor calculation

[Faul 2011] S. Faulstich, B. Hahn, P. J. Tavner: Wind turbine downtime and its importance for offshore deployment; Wind Energy Volume 14, Issue 3 p. 327-337, 2011; [Sheng 2016] Shuangwen (Shawn) Sheng: Report on Wind Turbine Subsystem Reliability – A Survey of Various Databases; National Renewable Energy Laboratory, 2013; [NSK 2009] Wälzlager-Doktor. Wartung von Wälzlagern. In: Motion & Control; [vH15] H. van Lier und C. Hentschke: Schädlicher Wälzlagerschlupf: Wann ist Wälzlagerschlupf schädlich und führt zum Ausfall des Wälzlagers?; Abschlussbericht ; Forschungsvorhaben Nr. 663 I. Bd. 1124. FVA-Heft. Frankfurt: FVA, 2015; [Schaeffler 2000] Schaeffler (2000): Wälzlagerschäden. Schadenserkennung und Begutachtung gelaufener Wälzlager.

Novel test method by metrological robustness evaluation

Gearbox test

Time-resolved records of input parameters



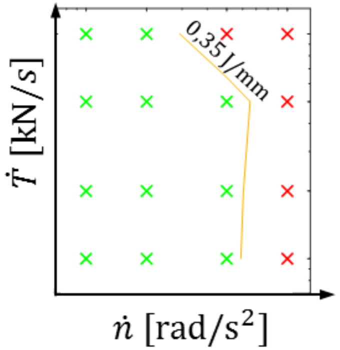
Damage hypothesis

e.g. smearing:

Damage hypothesis according to Wadewitz and Eglinger:

$$W_{R,spez} = \int_t^{t+t_{2b}} \int_t^{t+t_{2b}} \frac{\mu \cdot F_b(\tau) \cdot u_G(\tau)}{2b(\tau)} d\tau$$

Risk of a load case



Frequency

Frequency of a load case

- Weibull-distribution
- Special load cases
- Site/controller-specific

Evaluation of Robustness

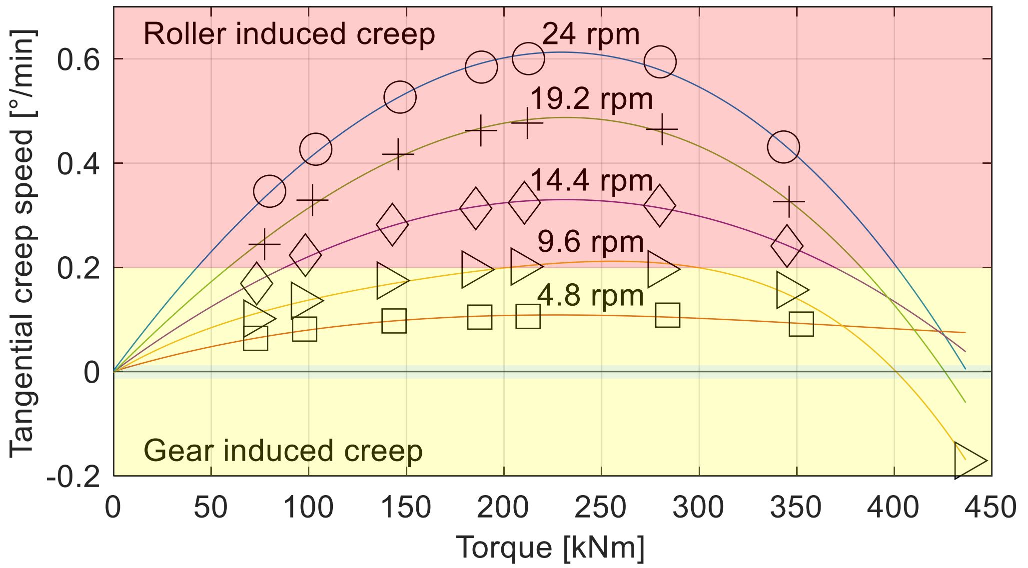
$$R_{\text{failure mode}} = \frac{\sum(\text{risk of a load case} * \text{frequency of a load case})}{\text{frequency of all load cases}};$$

$$0 \leq R \leq 1$$

Novel test method by metrological robustness evaluation

Ring creep

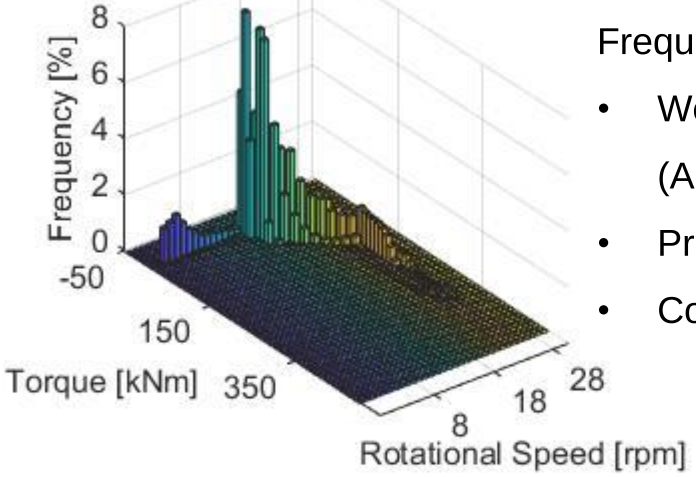
Ring creep speed at planetary bearing



Risk of a load case g_i (Assumption):

- Safe area: 0 ° /min -> g_{safe} = 1
- Transition area: < 0.2 ° /min -> g_{tran} = 0,5
- Critical area: > 0.2 ° /min -> g_{crit} = 0

Frequency



Frequency of a load case

- Weibull-distribution (A=7.99;k=2.19)
- Production DLC 1.1
- Controller-specific

Evaluation of Robustness

$$R_{\text{Ring Creep}} = 0.36$$

$$0 \leq R \leq 1$$

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