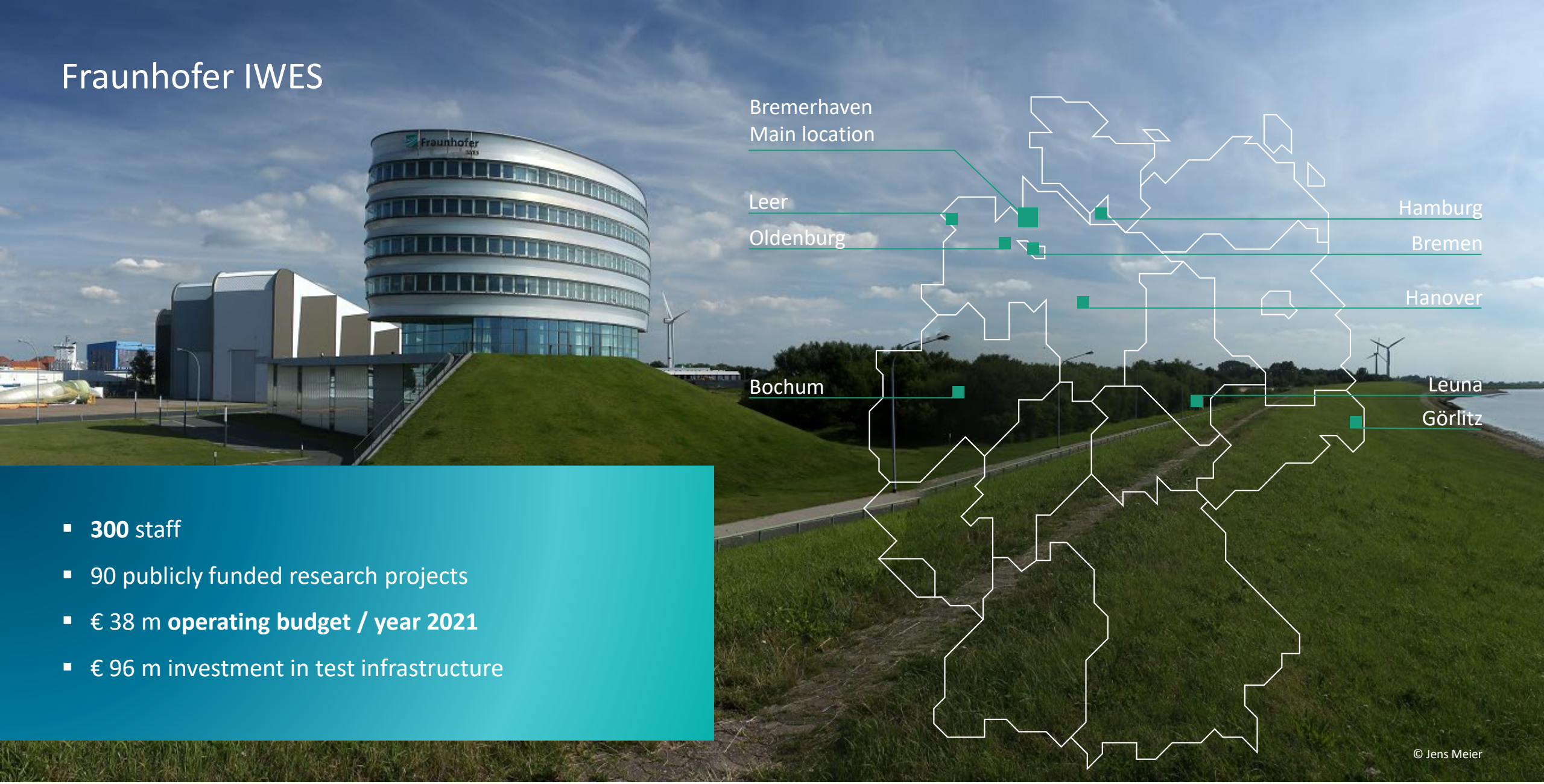
21.02.2023 / Drivetrain Reliability Collaborative Workshop

Review of Pitch Bearing Research related to the Design Guide Update

Oliver Menck

Fraunhofer IWES



- **300** staff
- 90 publicly funded research projects
- € 38 m **operating budget / year 2021**
- € 96 m investment in test infrastructure

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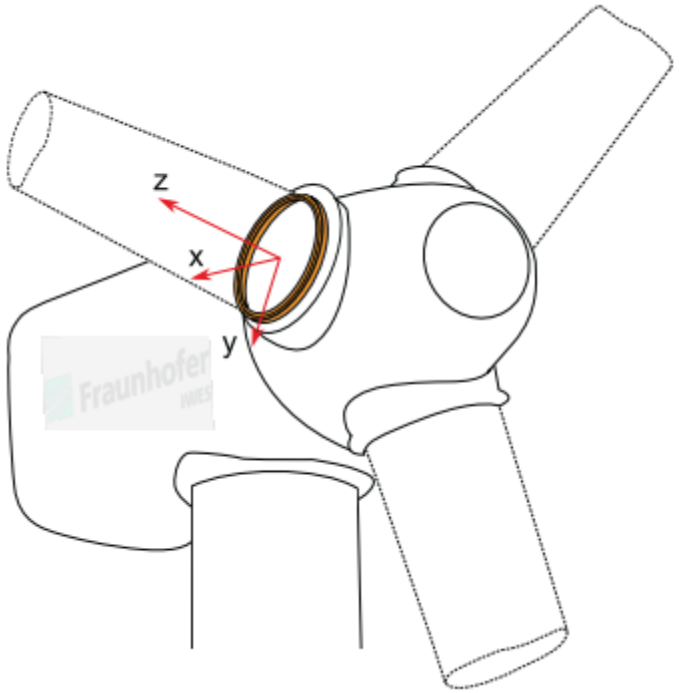
Large bearing laboratory



Stammler, Matthias (2020): Endurance test strategies for pitch bearings of wind turbines. Dissertation. Leibniz University Hannover.

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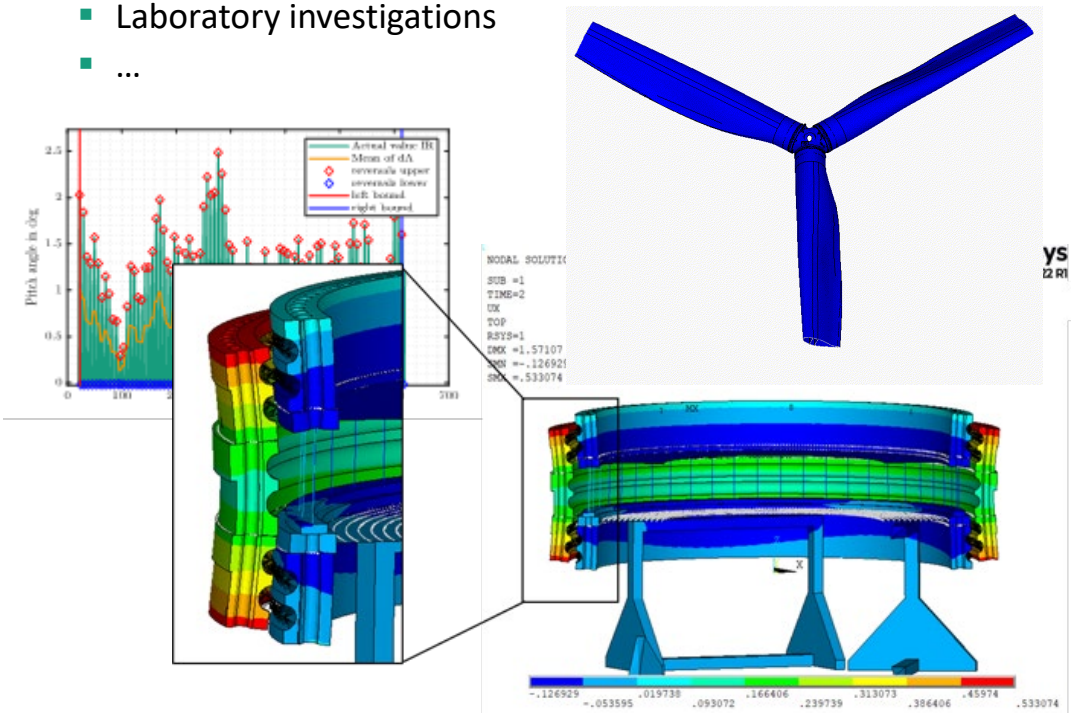
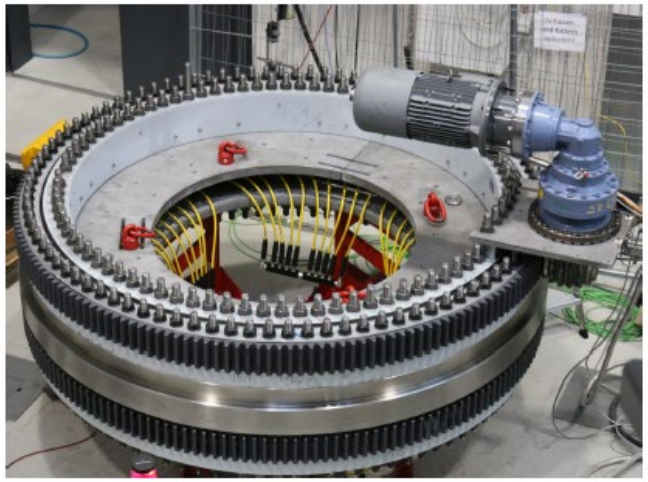
Large bearing laboratory

- Real-scale testing
- Data analysis and test methodology
- FE-Simulation and MBS
- Calculation methods, test rig design, automation
- Laboratory investigations
- …



(a) "BEAT1.1", for 0.7 m bearings (in metallic) ©Fraunhofer IWES/Ulrich Perrey

(b) "BEAT2.1", for 2 m bearings (at blade root) ©Fraunhofer IWES/Martina Buchholz



(c) "BEAT2.2", for 2 m bearings (in non-metallic gray, with gear teeth on outer ring) ©Fraunhofer IWES/Karsten Behnke

(d) "BEAT6.1", for 5 m bearings (in orange) ©Fraunhofer IWES/Marcus Heine

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DG03 and related research findings

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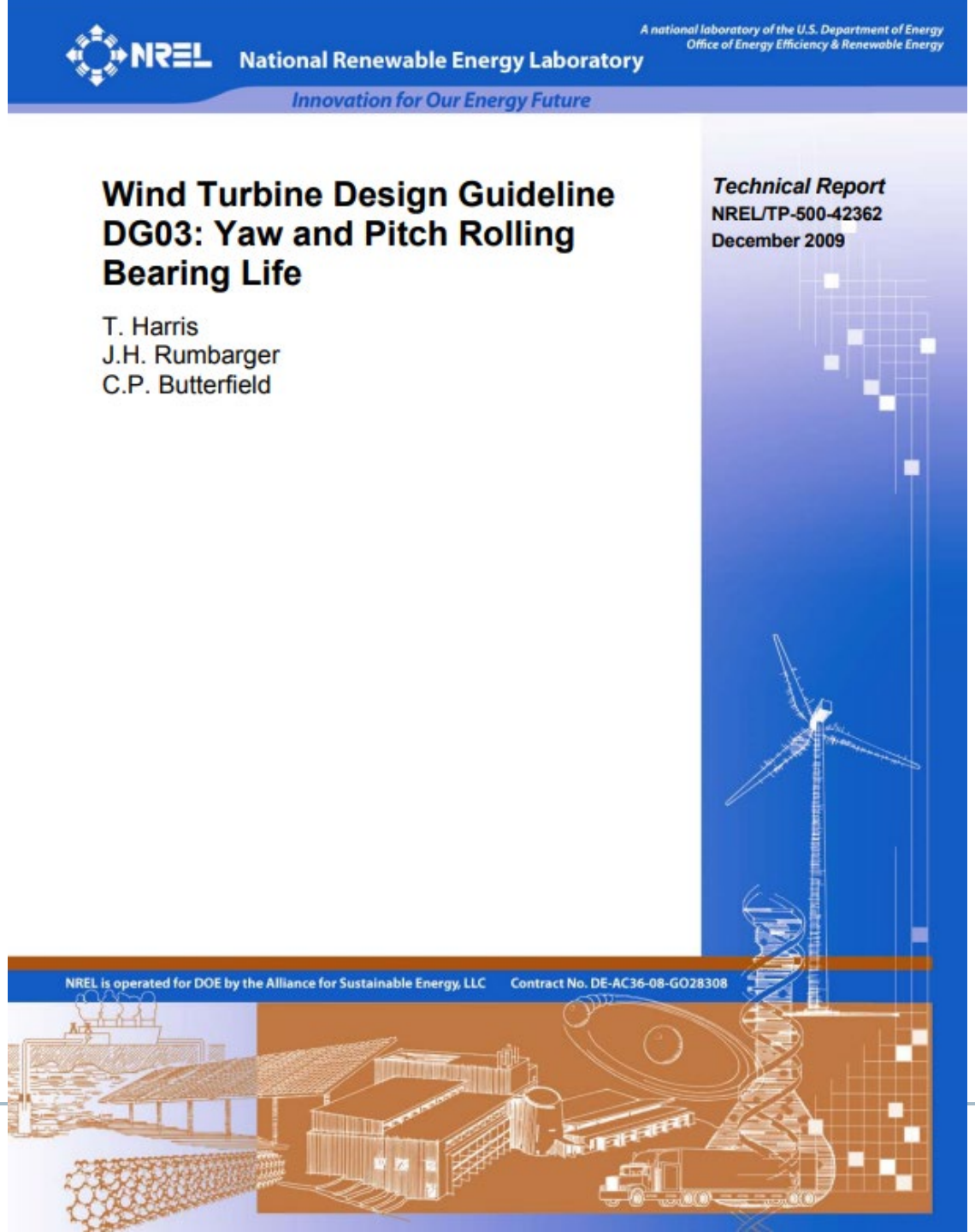
NREL DG03



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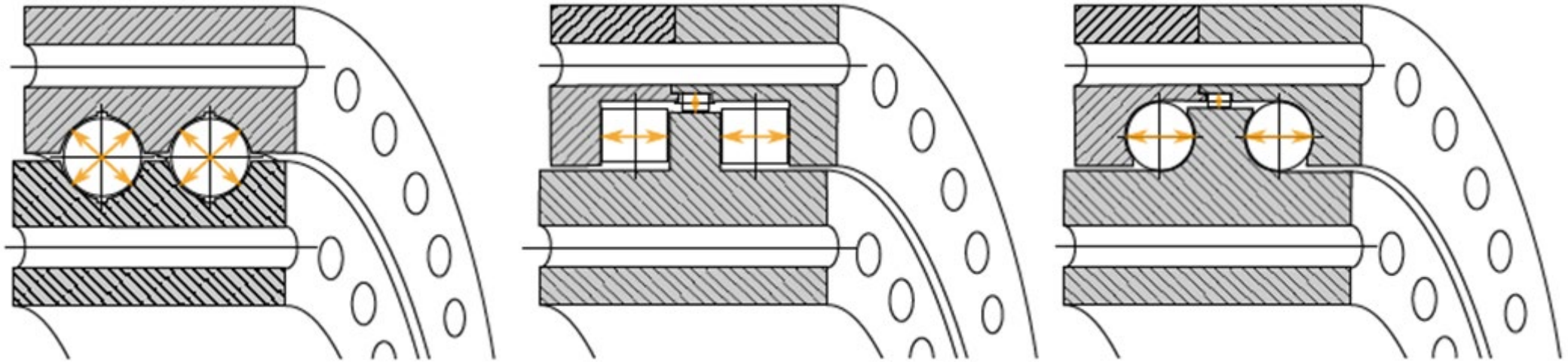
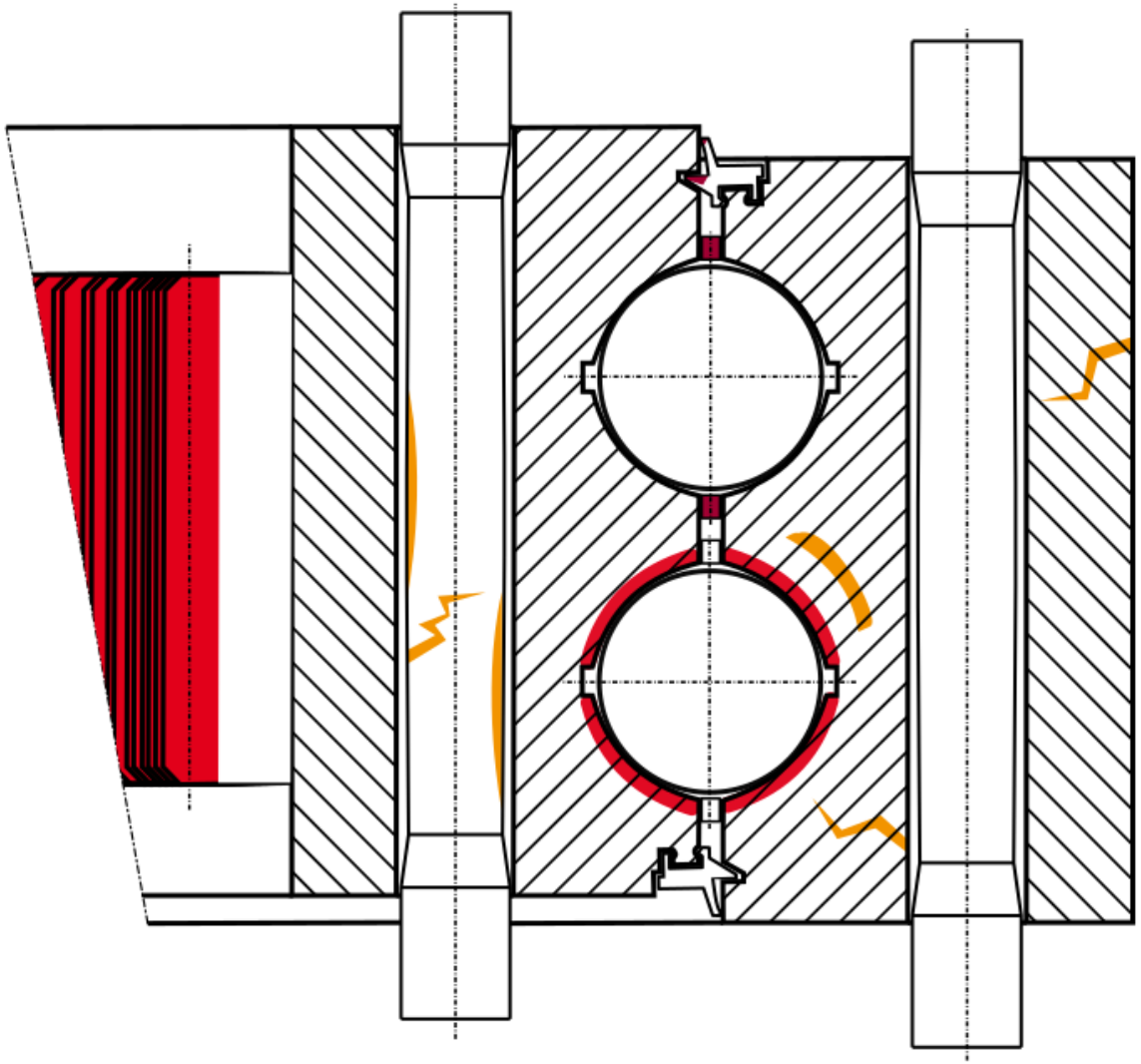
Blade bearings



Stammler, Matthias (2020): Endurance test strategies for pitch bearings of wind turbines. Dissertation. Leibniz University Hannover.

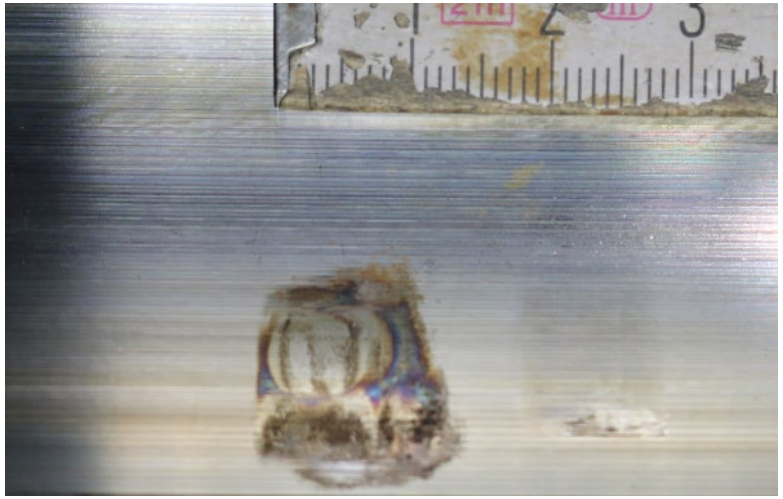


Stammler, Matthias (2020): Endurance test strategies for pitch bearings of wind turbines. Dissertation. Leibniz University Hannover.

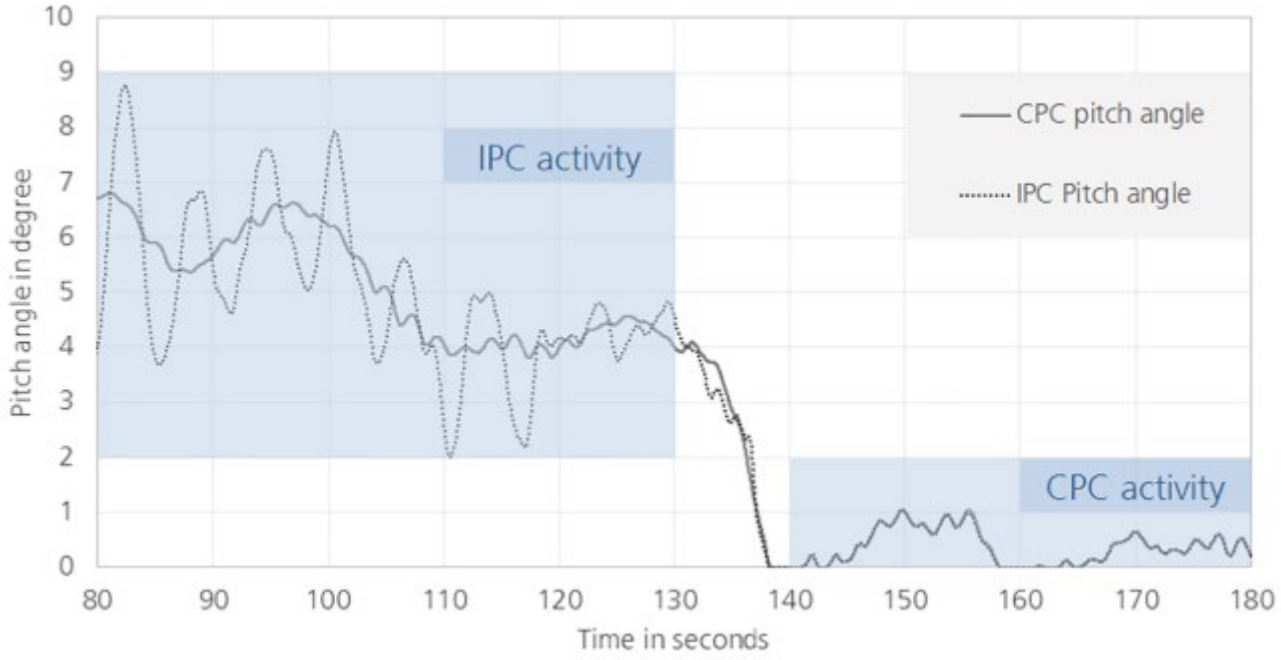
Wear

Probably not that critical.

- With the right grease (low viscosity)
- If there are occasional larger movements
- IPC better than CPC?



HAPT project results



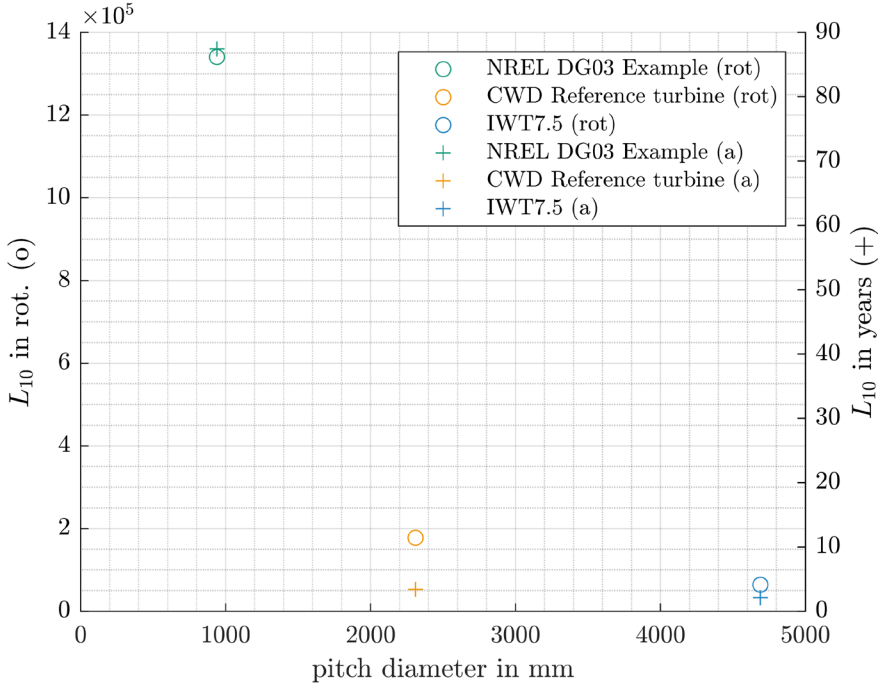
Stammler, Matthias; Thomas, Philipp; Reuter, Andreas; Schwack, Fabian; Poll, Gerhard (2020): Effect of load reduction mechanisms on loads and blade bearing movements of wind turbines. In: Wind Energy 23 (2), S. 274–290. DOI: 10.1002/we.2428.

Raceway Fatigue

It happens, but the calculations aren‘t fully accurate.

- Empirical life higher than calculations?
- Happens though, despite relatively small movement
- Larger bearings ⟶ higher failure risk
- Four-point bearings can still be operated with severe damage

Verbundprojekt HBDV - Auslegung hochbelasteter Drehverbindungen; Teilprojekt: Validierung der Berechnungsansätze mittels geraffter Tests im Originalmaßstab: Abschlussbericht



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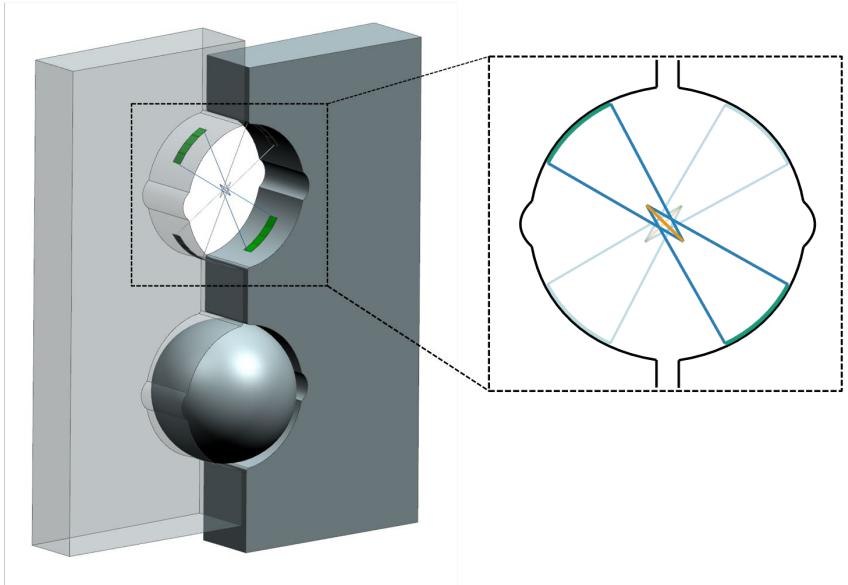
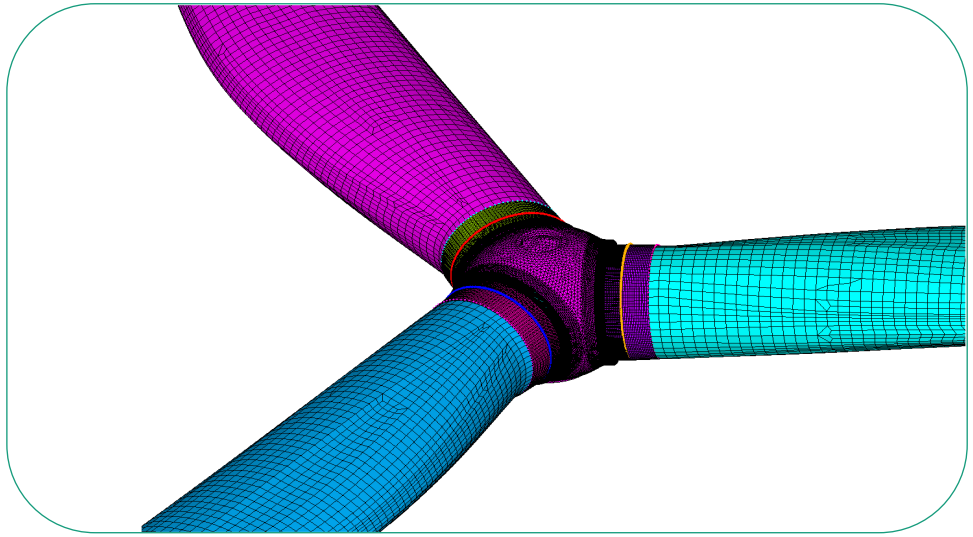
FE simulations

Pitch bearing simulations without interfaces are wrong.

- Stiffnesses of surrounding structures!
- Rolling elements can be modeled OK using springs
- FE simulations are really, really critical to the bearing design.

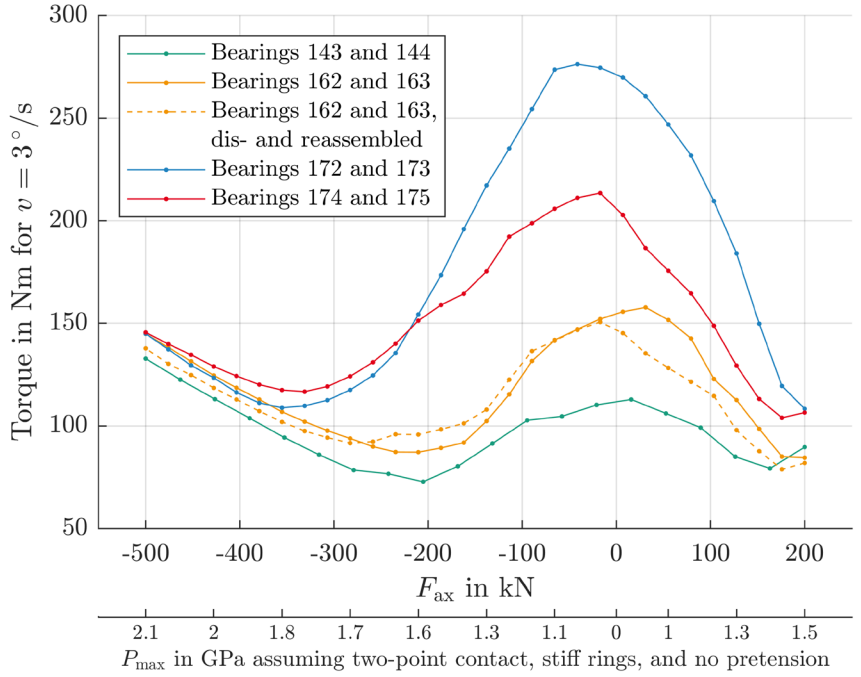


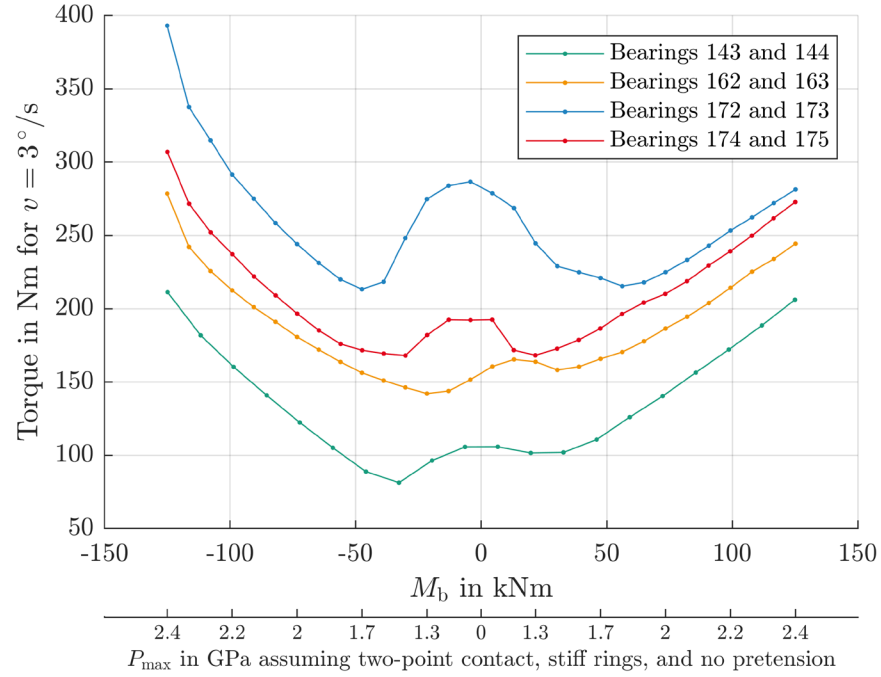


Friction Torque

More difficult than you would expect

- Lots of variation
- Four-point to two-point transition
- Scaling is tricky





Menck, O.; Behnke, K.; Stammler, M.; Bartschat, A.; Schleich, F.; Graßmann, M. (2022): Measurements and modeling of friction torque of wind turbine blade bearings. In: J. Phys.: Conf. Ser. 2265 (2), S. 22087. DOI: 10.1088/1742-6596/2265/2/022087.

Current research

Ring fatigue

Interdependencies (e.g. Wear & RCF, RCF & Ring cracks?)

Condition Monitoring

Digital Twin

Scaled testing methodologies

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Thanks a lot for your attention!

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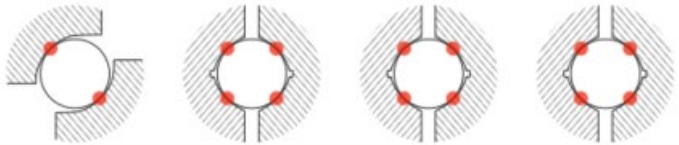
Diameter	0.14	0.67	2.3	4.7
Type				
Wear	1		5	1
RCF				2 6
Endurance	⊘	⊘	⊘	1
Friction	⊘	4	3 4	4
FE Model			5	2

1 Stammler, M. (2020) *Endurance Test Strategies for Pitch Bearings of Wind Turbines*, Fraunhofer Verlag, Stuttgart.

2 Menck, O., Stammler, M., Schleich, F. (2020) *Fatigue lifetime calculation of wind turbine blade bearings considering blade-dependent load distribution*. Wind Energ. Sci., 5 (4), 1743–1754.

3 Stammler, M., Schwack, F., Bader, N., Reuter, A., Poll, G. (2018) *Friction torque of wind-turbine pitch bearings – comparison of experimental results with available models*. Wind Energ. Sci., 3 (1), 97–105.

4 Menck O, Behnke K, Stammler, M, Bartschat A, Schleich F, Graßmann M (2022) *Measurements and modeling of friction torque of wind turbine blade bearings*. J. Phys.: Conf. Ser., 2265.

5 Behnke, K. and Schleich, F. (2022) *Exploring Limiting Factors of Wear in Pitch Bearings of Wind Turbines with Real Scale Tests*. Wind Energy Science, 2022, 1–22.

6 Menck, O. (2023) *The Finite Segment Method - A Numerical Rolling Contact Fatigue Life Model for Bearings Subjected to Stochastic Operating Conditions*. J. Tribol., 145 (3).

Publication in work

No publication planned

Thanks a lot for your attention!

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