Blade Bearing Test Rig

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Motivation

Unfavorable operating conditions:

- High bending moments while standing still or rotating at very low speeds
- Surrounding parts, especially the rotor blade, relatively soft => deformation

Currently available calculation methods not suitable for the conditions found in rotor-blade bearings. Therefore, no reliable prediction of their lifetime.

Blade bearing tests are necessary

Comparatively high effort for repair or exchange

Defining a Blade Bearing Test Strategy

FMEA

Field experience

Expert workshop

- Possible damage modes
- Loads
- Pitch strategy
- Environment
- Deformation
- Relevance / prioritization

Verification Matrix

Market survey:
OEMs, suppliers,
institutes

- Verification (test) strategy
- Test rig specification containing:
  - Basic concept
  - Part dimensions
  - Metrology requirements
  - Load envelopes

Damage Modes

- Possible damage modes of the bearing include:
  - Fatigue
  - Edge loading
  - Core crushing
  - Ring fractures
  - Fretting
  - False brinelling

False Brinelling

Fretting Corrosion

Source: GREBE, M., FEINLE, P., HUNSICKER, W.

Findings from Blade Bearing FMEA

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Verification of lifetime!!

Assess behaviour of cage type bearings

Deformation of bearing and sealings under load

Simulation of current passages?

Suitable hardness penetration?

Measure real deformation during test campaigns

Considering stiffness of the surrounding structures

Effects types of wear and fatigue

Compare cage- and separator type bearings

Comparison of different lubricating grease

Layout of the lubrication system

Know real load distribution

Findings and Ranking from Blade Bearing Workshop

Requirements / Topics to Consider / Expected Outcome	Rank	Weight
Validate FEA calculations by measurements	1	8.6%
Ensure real proportion of bending moment and radial force	1	8.6%
Consider extreme loads*	3	8.3%
Apply realistic load cases	4	7.9%
Consider operational loads	5	7.6%
Measure bearing friction	6	6.9%
Consider individual pitch control	6	6.9%
Know bolt load distribution	8	6.7%
Essential Measurements and Verifications	**Rank**	**Weight**
Measure deformation of bearing, blade brace plate, hub	1	21.4%
Estimate influence of brace plate**	2	19.0%
Consider stiffness distribution of the root	2	19.0%
Use real blade or dummy	4	16.7%
Consider nonsinusodial load introduction	5	14.3%
Estimate influence of single load introduction via one bearing**	6	4.8%
Consider effects of test rig hub position**	6	4.8%

* up to the limits of blade dummy
** done by additional feasibility study

Verification Matrix

	Calculation	Testing	Field Validation
	Ultimate Load Verification		
Ring/Bolt Strength Raceway Strength Gear Strength	FEA ISO76, FEA ISO6336	Blade Test Full Scale Test Rig Component Test	
	Lifetime Verification		
Ring/Bolt Fatigue Raceway Fatigue/Wear Gear Fatigue/Wear	FEA ISO281/Method ISO6336	Blade Test Full Scale Test Rig / Scaled Tests	Field Returns Inspection
	Functional Verification		
Friction Torque Suitability of Sealings Stiffening Ring Grease Suitability	Different Calculation Approaches FEA	Full Scale Test Rig Full Scale Test Rig Full Scale Test Rig Scaled Test Rig	Monitoring Inspection Grease Samples

Verification concept includes:
Blade test, fullscale test rig and scaled tests

Market Survey Blade Bearing Testing - State of the Art

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Blade Bearing Test Rigs at OEMs

- Some OEMs have developed blade bearing test rigs which most likely:
  - Are pitchable under load
  - Cover nominal (mostly static) load
  - Include the surrounding structure of hub and blade

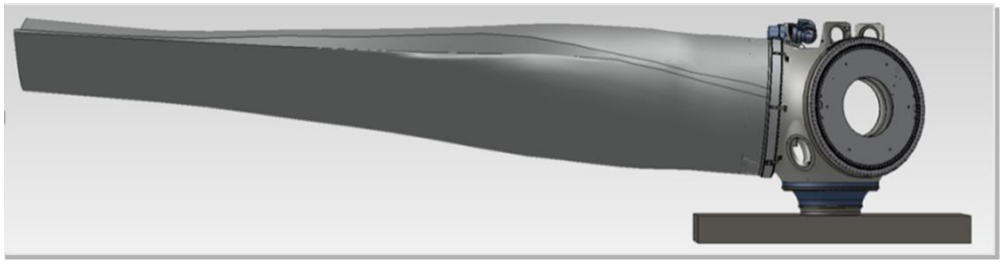
Blade Bearing Test Rigs at Suppliers‘ Facilities

- Several suppliers use blade bearing test rigs which are:
  - Non compatible to our surrounding structure
  - Used for smaller size bearings and smaller loads

Blade Bearing Test Rigs at External Institutes

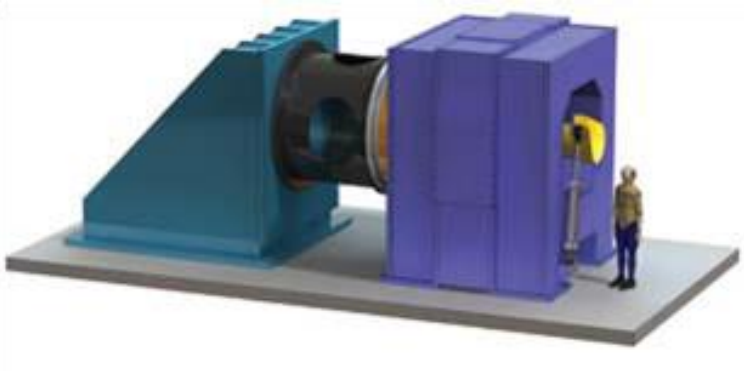
- Several big test institutes can build test rigs which:
  - Are pitchable under load
  - Cover Nominal (mostly static) load
  - Include the surrounding structure of hub and blade

Summarized Scope

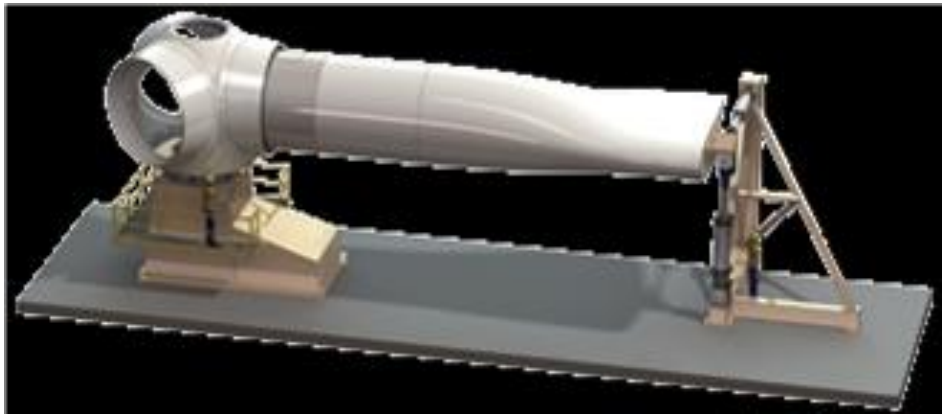


- Verification at extreme loads
  - Sealing behaviour
  - Bolt stress
  - Ultimate strength of bearing rings
- Detailed evaluation of operational behavior:
  - Bearing friction under load
  - Compare different bearing concepts
  - Lubricant distribution
- Validation of models and assumptions with repeatable load cases
- Evaluate lubrication conditions as essential prerequisite for downscaled (and accelerated) life cycle verification

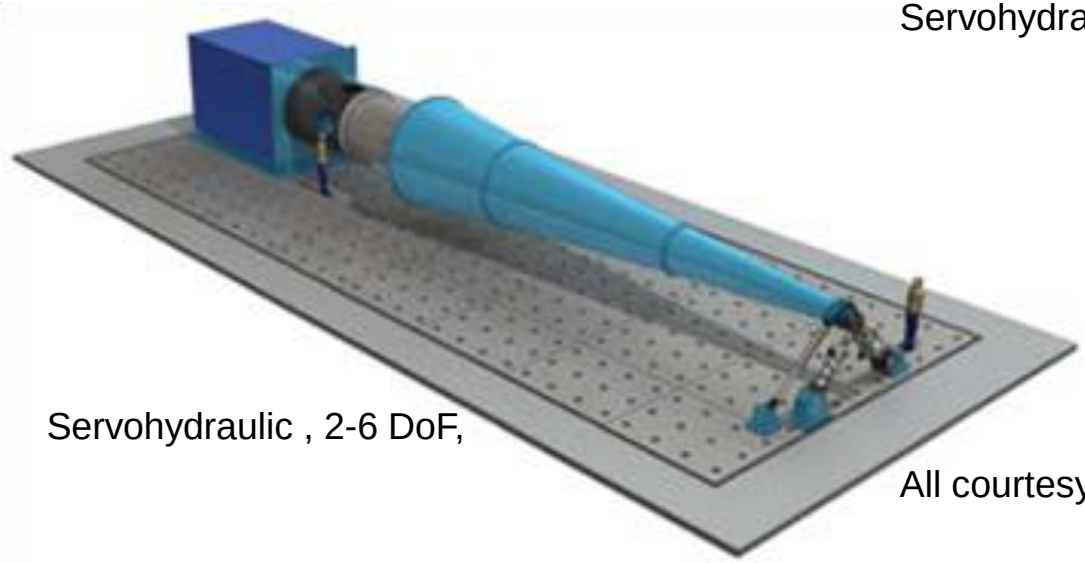
Possible Concepts



Hydrostatic, 6 DoF,



Servohydraulic , 2-6 DoF,



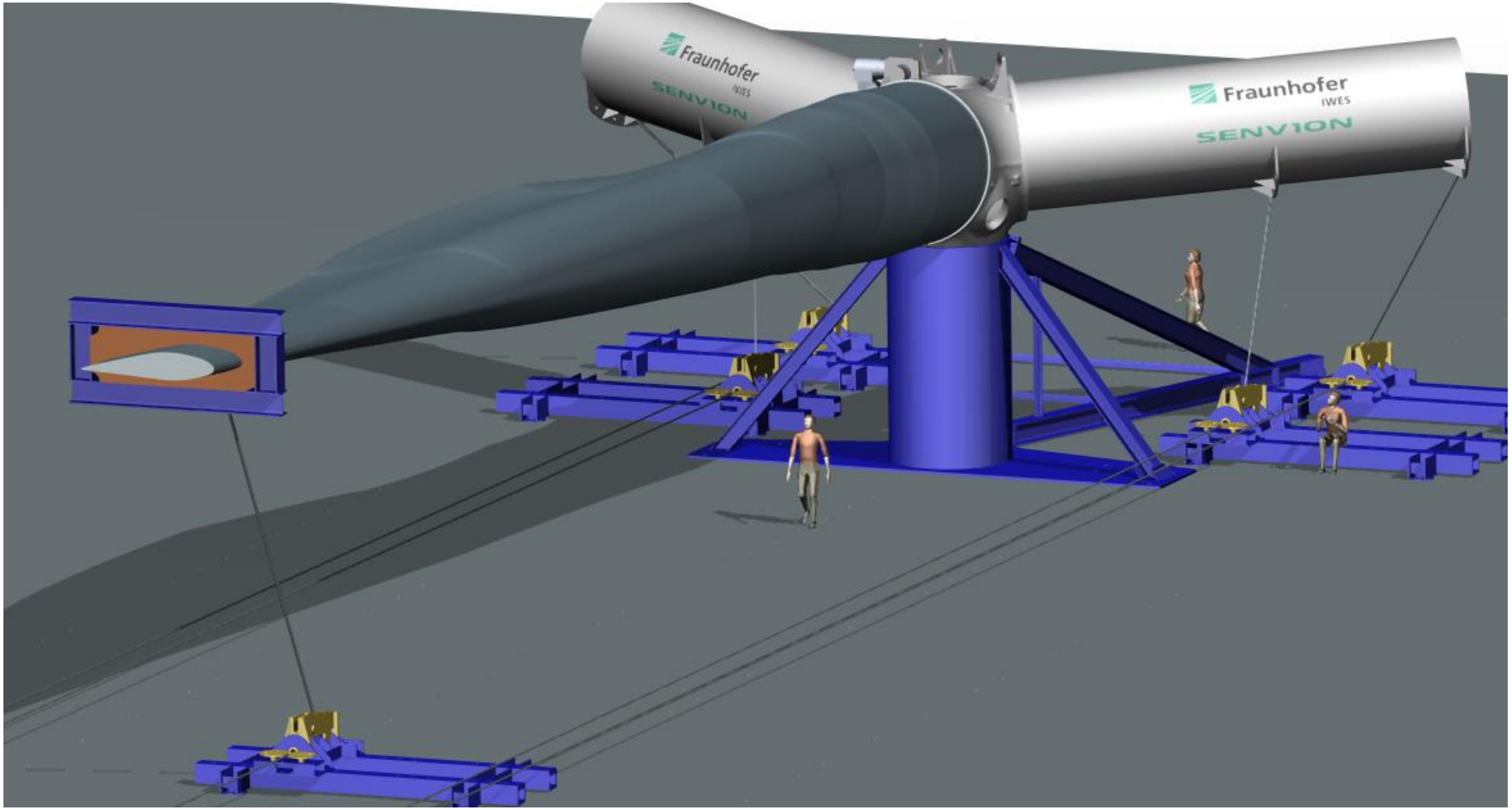
Servohydraulic , 2-6 DoF,

All courtesy of MTS

Test Rig Concept

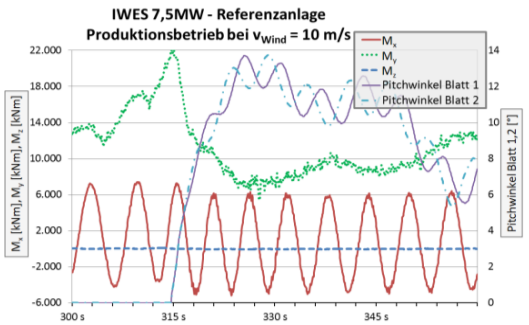
- „Star“ layout for realistic hub deformation
- Components from WEC: Hub, bearing, blade, pitch drive
- Load application point at 30 m from blade root
- Load up to max. static load
- Load application under different angles
- Control software for pitch profiles
- Appr. 400 channels measurement system
- Additional standalone systems for high speed measurements

Test Rig Concept

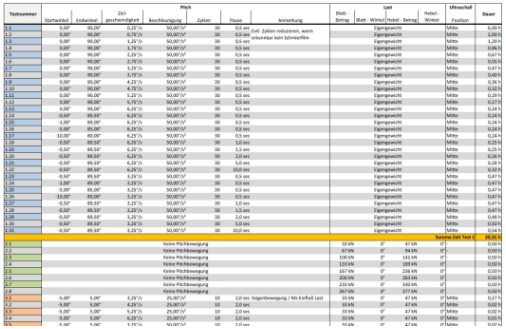


Test Strategy

- Functional & research test
- Pitch under load with different amplitudes
- Apply maximum loads
- Derive possible endurance run profiles



Mittlere Amplitude	Anzahl Zyklen	Mittlere Frequenz	Standardab-weichung Amplitude	Mres (Mittel)	Mres (Standardab-weichung)
[deg]		[Hz]	[deg]	[normiert]	[normiert]
0,27	4,14E+07	0,96	0,15	0,95	0,045
0,79	3,25E+07	0,49	0,14	1,00	0,063
1,28	2,30E+07	0,46	0,14	0,99	0,068
1,79	1,27E+07	0,42	0,14	0,94	0,074
2,27	7,51E+06	0,38	0,13	0,86	0,082
2,79	5,70E+06	0,33	0,14	0,80	0,090



Test Rig – Current Status

Status Full Scale Test

Achieved

- Test rig based on original hub and strengthened blade
- Start of friction test series
- Senvion parts and steel structures on site

Upcoming

- Produce instrumented bearing
- Design an produce lubrication sensor
- Commissioning
- Start functional testing