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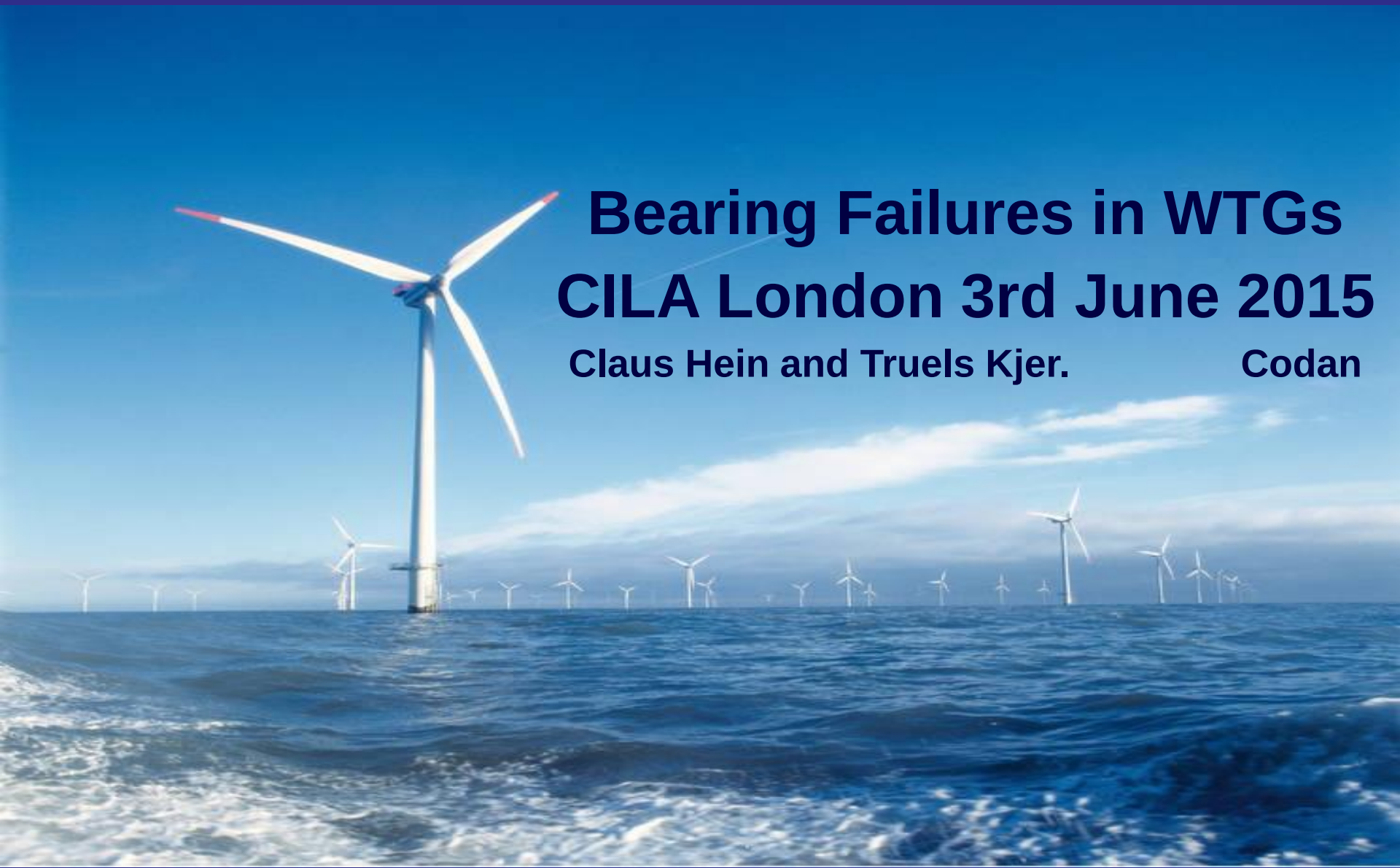

Bearing Failures in WTGs
CILA London 3rd June 2015

Claus Hein and Truels Kjer. **Codan**

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- About Us
- An Engineer's Perspective
- Claims Perspective
- Legal Viewpoint and Developments
- Q & A

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About Us

CODAN

INTRODUCING RSA & CODAN

RSA AND CODAN HAS A STRONG AND WELL-BALANCED PORTFOLIO WITH MAJOR OPERATIONS ACROSS THE GLOBE

HERITAGE
FTSE100 listed general insurer and a leading provider of commercial insurance for more than 300 years.

STRONG GLOBAL PORTFOLIO
UK & Western Europe, Canada, Scandinavia, Latin America and the Middle East.

SCALE
17 million customers in more than 140 territories; approx 20,000 employees.

MARKET-LEADING UNDERWRITING
Strong reputation for technical excellence.

CREDIT RATING
RSA is financially strong. S&P rated: A.

CORPORATE SOCIAL RESPONSIBILITY
The first carbon neutral insurer.

CUSTOMER-LED SERVICE DELIVERY
Knowledge and understanding of customer need tailors our service.

CODAN

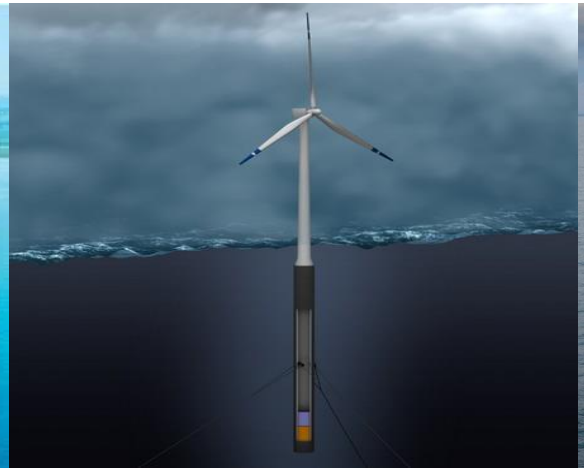
FOLLOWING OUR CLIENTS… WHEREVER THEY GO

First Onshore Wind Farm

First Offshore Wind Project in the world

First Floating Wind Turbine

First Offshore Grid / Cluster



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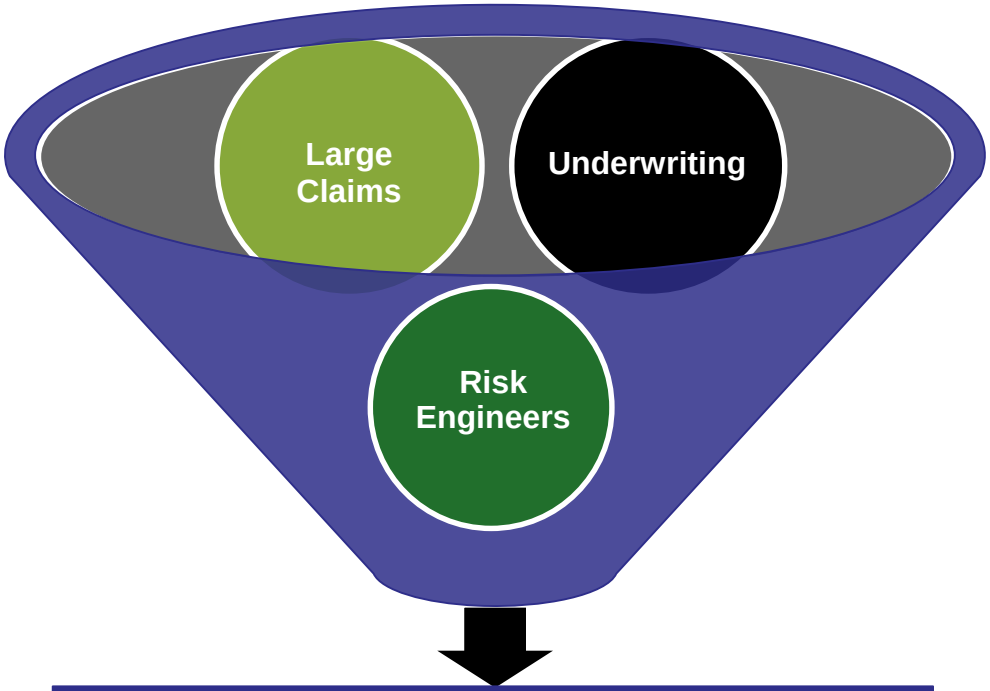
THE RSA CENTRE OF EXCELLENCE



Centre of Excellence - Wind

- Underwriting Issues
- Risk Improvement / Recommendations
- Claims
- Market Standards

CODAN

WORKING WITH PROMINENT PLAYERS

Manufacturers

Vestas
SIEMENS
ALSTOM
Gamesa
TenneT Taking power further
AREVA
acciona
REpower Systems

Innovative clients

STATOIL
e.on
EDISON
RWE
EnBW Energie braucht Impulse
VATTENFALL
Statkraft
centrica
npower
DONG energy
EDF energies nouvelles
Scottish and Southern Energy

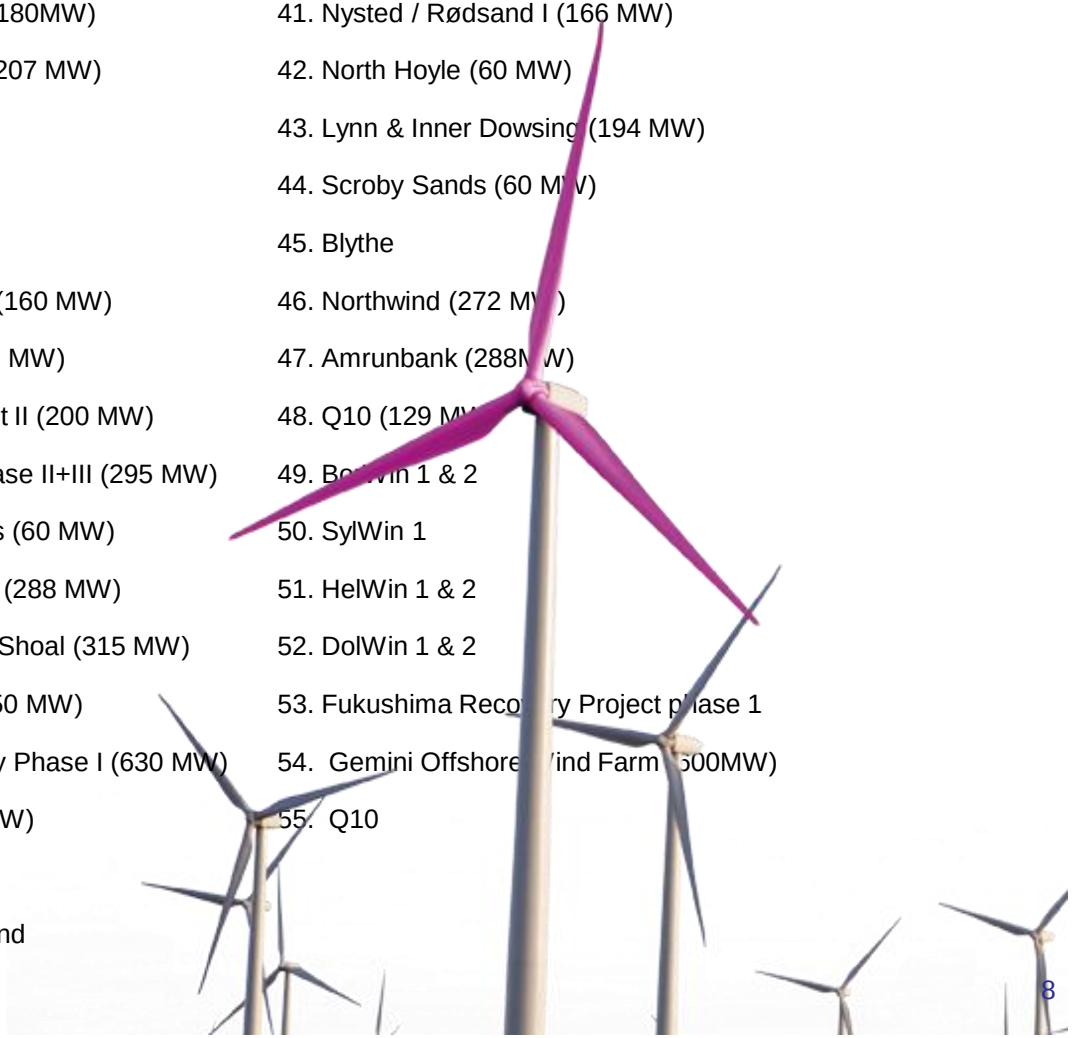
Leading brokers

Willis LESS RISK. MORE VALUE
MARSH
AON
Lampe & Schwartze ASSEKURANZVERMITTLUNG
JLT
LOCKTON

CODAN

PROVIDING CAPACITY TO 80 % OF THE WORLDS OFFSHORE WINDFARMS

1. West of Dudden Sands (389 MW)
2. Gwynt Y môr (576 MW)
3. Global Tech I (400 MW)
4. Dan Tysk (288 MW)
5. Baltic II (288 MW)
6. Riffgat (108 MW)
7. Meerwind (288 MW)
8. Butendiek (288MW)
9. Karehamn (48 MW)
10. Humber Gateway (220 MW)
11. Teesside (62 MW)
12. Baltic I (48MW)
13. Robin Rigg (180MW)
14. Barrow (90 MW)
15. Burbo Bank (90 MW)
16. Kentish Flats (90 MW)
17. Greater Gabbard (504 MW)
18. Thanet (300 MW)
19. Lillgrund (110 MW)
20. Horns Rev II (209 MW)
21. Rhyl Flats (90 MW)
22. Robin Rigg (180MW)
23. Rødsand II (207 MW)
24. Wave Hub
25. Samsø
26. *Hywind*
27. Horns Rev I (160 MW)
28. Lillgrund (110 MW)
29. Borkum West II (200 MW)
30. C-Power Phase II+III (295 MW)
31. Alpha Ventus (60 MW)
32. Nordsee Ost (288 MW)
33. Sheringham Shoal (315 MW)
34. Ormonde (150 MW)
35. London Array Phase I (630 MW)
36. Lincs (270 MW)
37. Utgrunden
38. Ytre Stengrund
39. *Vindeby*
40. Bockstiegen
41. Nysted / Rødsand I (166 MW)
42. North Hoyle (60 MW)
43. Lynn & Inner Dowsing (194 MW)
44. Scroby Sands (60 MW)
45. Blythe
46. Northwind (272 MW)
47. Amrunbank (288MW)
48. Q10 (129 MW)
49. BorWin 1 & 2
50. SylWin 1
51. HelWin 1 & 2
52. DolWin 1 & 2
53. Fukushima Recovery Project phase 1
54. Gemini Offshore Wind Farm (600MW)
55. Q10



CODAN

YOUR STABLE AND LONG TERM PARTNER

Codan has insured wind turbine projects from the very beginning…

... and we have kept this business even through the very bad times

… we are here for you now

… and we will be here in the future

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An Engineer’s Perspective

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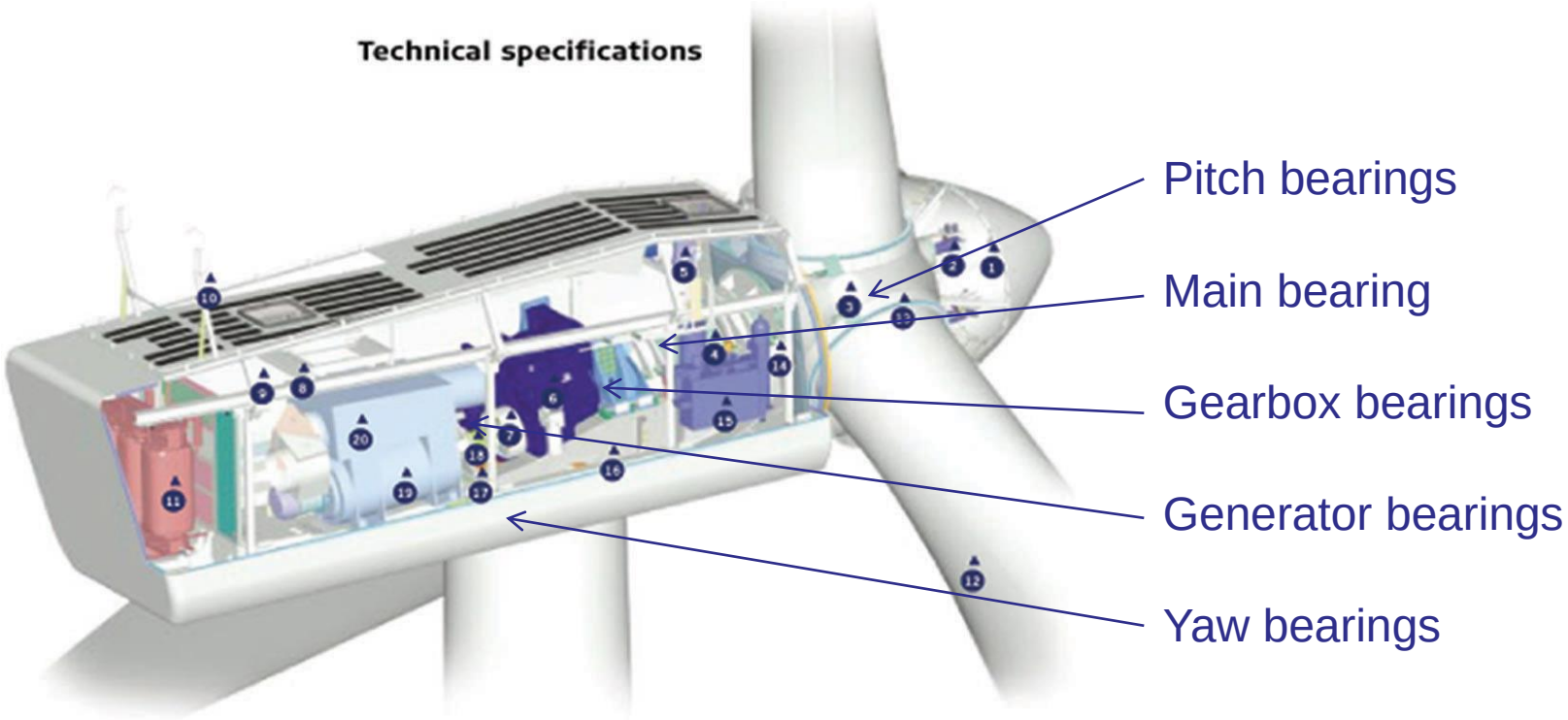
Bearings in a typical Wind Turbine



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Typical Bearing Failures

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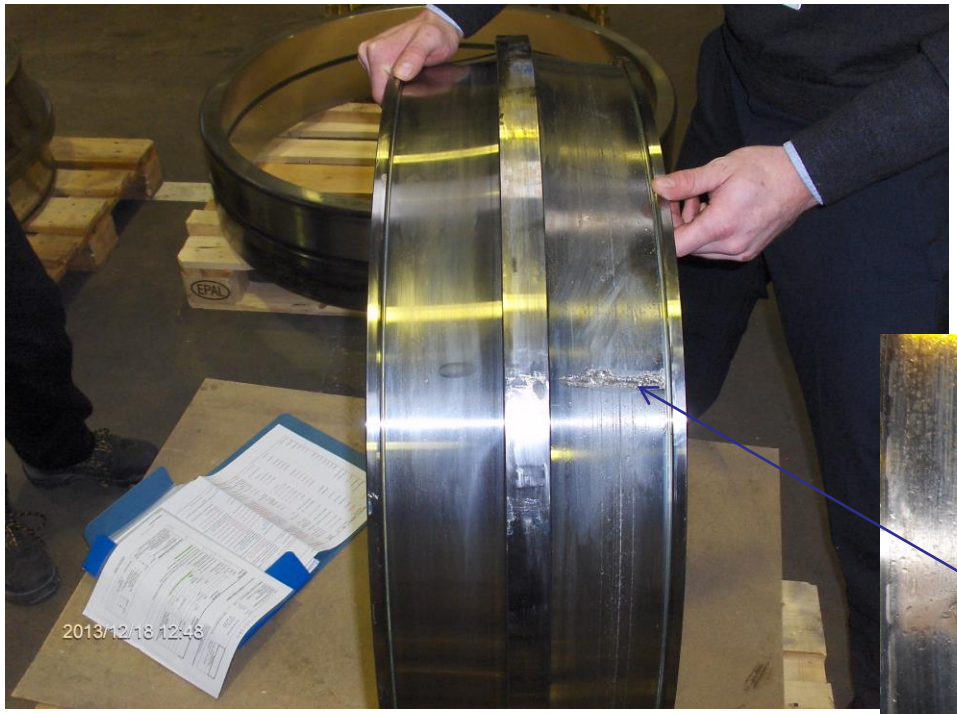
Main Bearing - Pitting and Spalling



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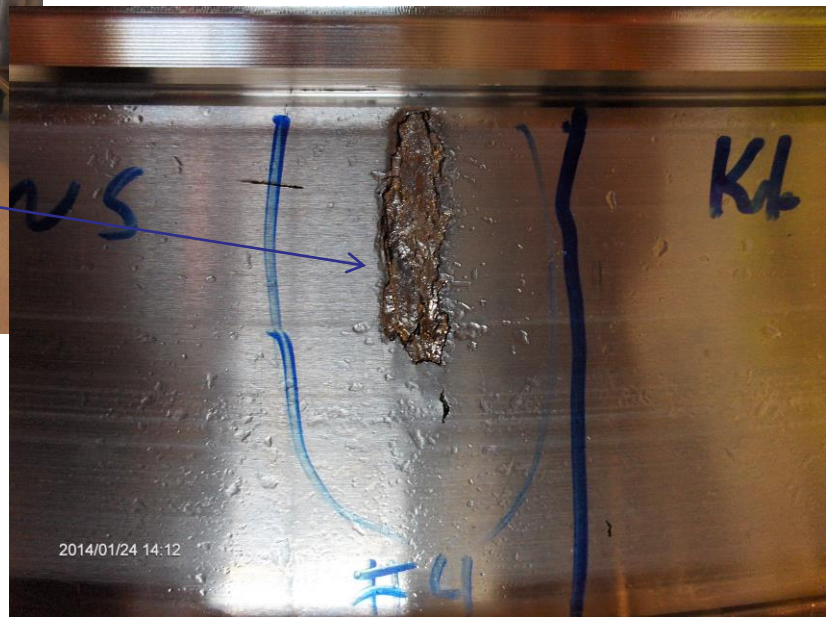
Large Main Bearing in Direct-Drive Turbines



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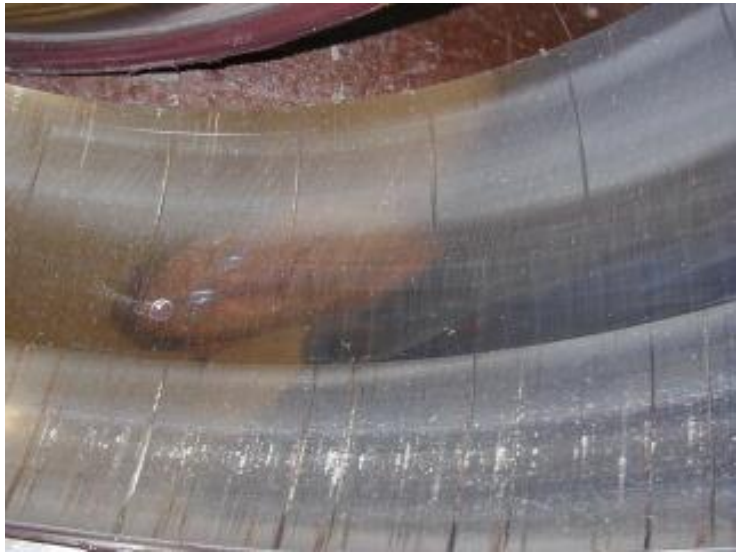
Spherical Roller Bearings – Stand-Still marks



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ISO 15243

Rolling bearings – Damage and failures - Terms, characteristics and causes

ISO 15243:2004 defines, describes and classifies the characteristics, changes in appearance and possible causes of failure of rolling bearings, occurring in service.
It will assist in the understanding of the various forms of change in appearance and the failure that has occurred.
Consideration is restricted to characteristic forms of change in appearance and failure, which have a well-defined appearance and which can be attributed to particular causes with a high degree of certainty.
The features of particular interest for explaining changes and failures are described.
The various forms are illustrated with photographs and diagrams, and the most frequent causes are indicated.

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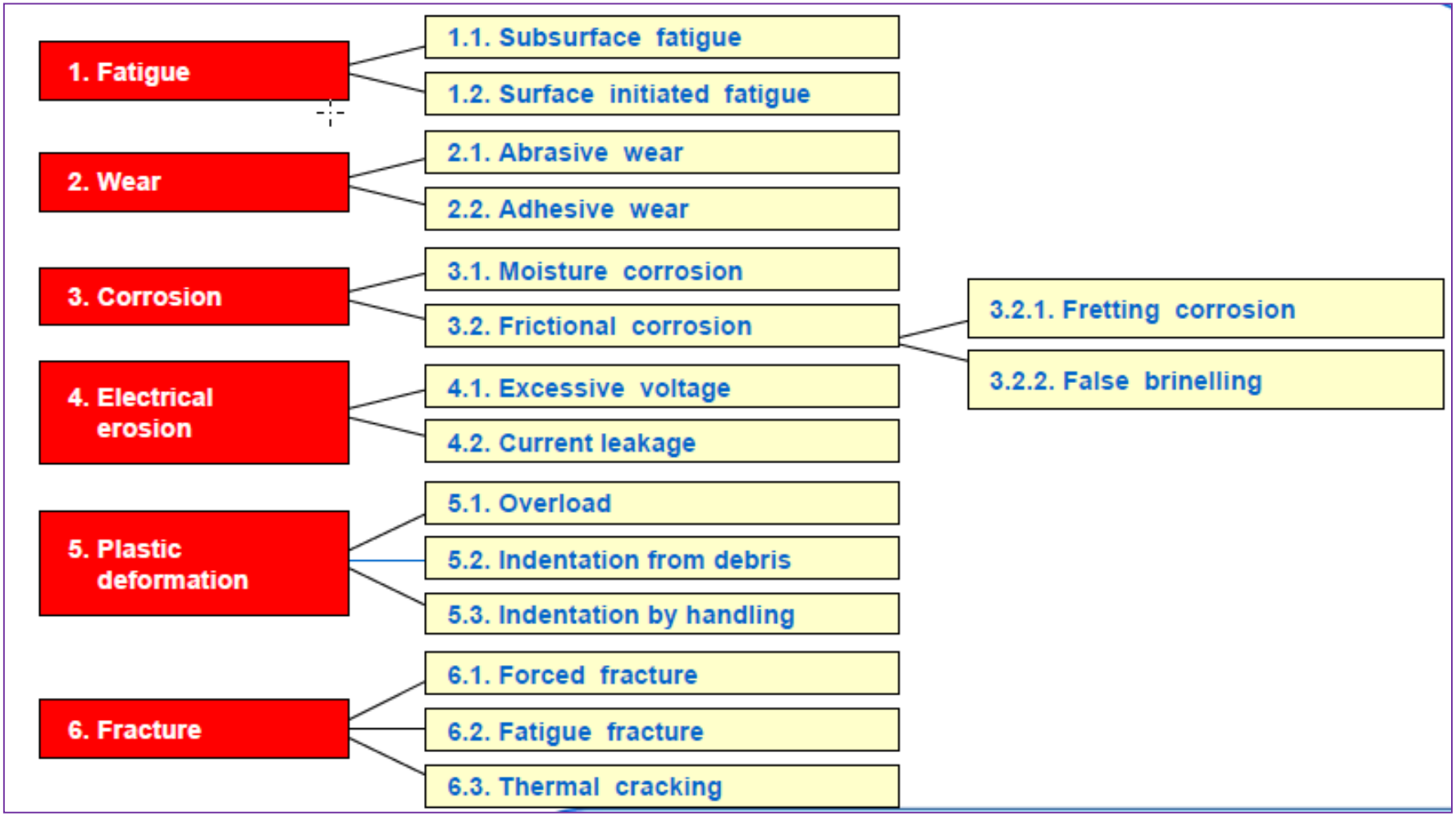
Bearings – Failure mode classification according to ISO 15243



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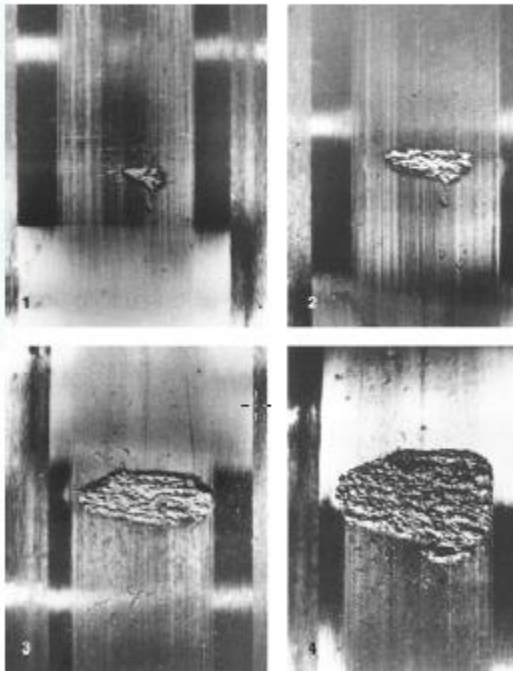
Bearings – Failure mode classification according to ISO 15243

- 1. Fatigue
  - 1.1. Subsurface fatigue
  - 1.2. Surface initiated fatigue
- 2. Wear
- 3. Corrosion
- 4. Electrical erosion
- 5. Plastic deformation
- 6. Fracture

- repeated stress changes
- material structural changes
- micro-cracks under the surface
- crack propagation
- flaking, spalling & peeling

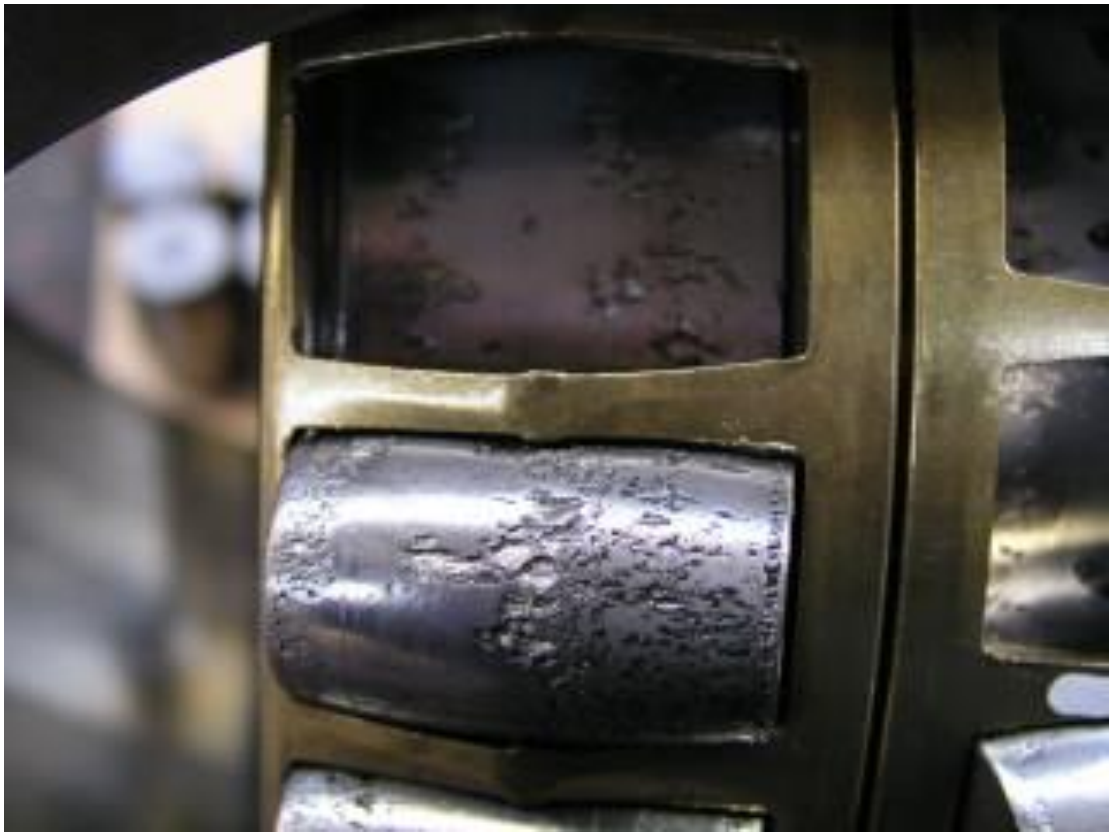


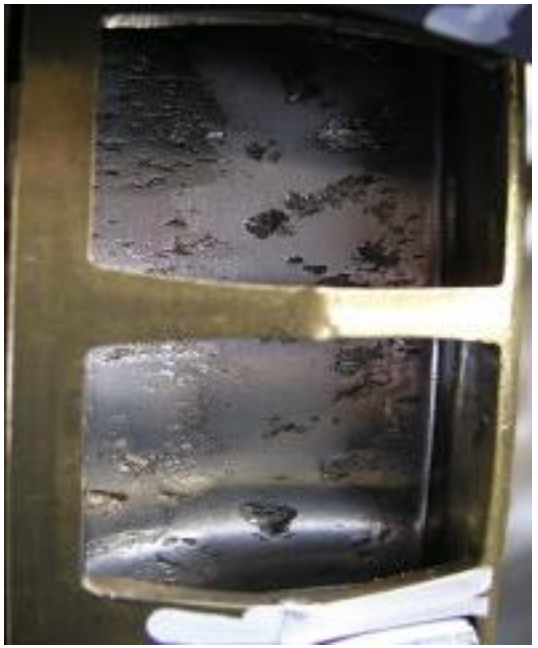
CODAN

Bearings – Failure mode classification according to ISO 15243

CODAN

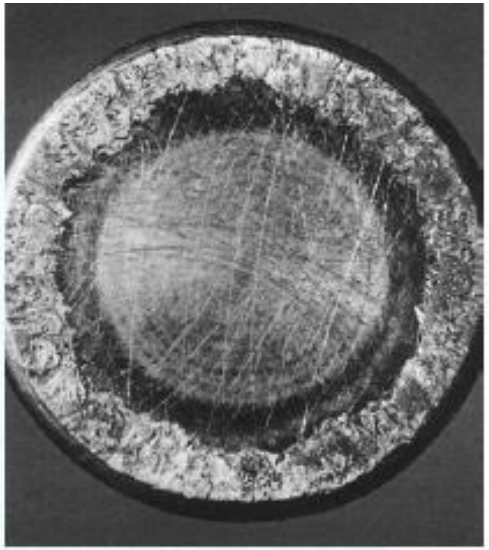
Bearings - Abrasive Wear





CODAN

Bearings – Failure mode classification according to ISO 15243



1. Fatigue
2. Wear
   - 2.1. Abrasive wear
   - 2.2. Adhesive wear
3. Corrosion
4. Electrical erosion
5. Plastic deformation
6. Fracture

- accelerations
- smearing / skidding / galling
- material transfer / friction heat
- tempering / rehardening with stress concentrations and cracking or flaking
- low loads

CODAN

Bearings – Failure mode classification according to ISO 15243

1. Fatigue
2. Wear
3. Corrosion
   - 3.2. Moisture corrosion
   - 3.1. Frictional corrosion
     - 3.2.1. Fretting corrosion
     - 3.2.2. False brinelling
4. Electrical erosion
5. Plastic deformation
6. Fracture

- micro movement between mating parts
- oxidation of asperities
- powdery rust / loss of material
- occurs in interfaces transmitting loads

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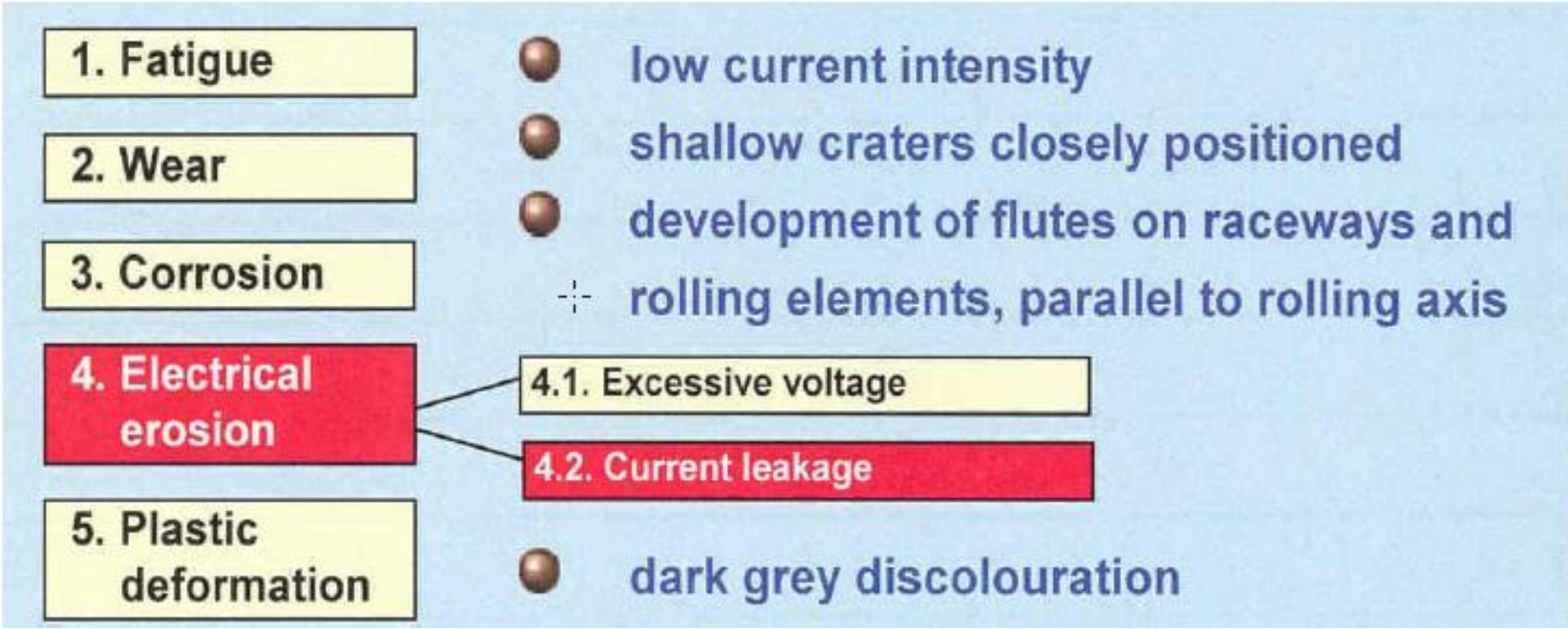
Bearings – Failure mode classification according to ISO 15243



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Bearings - Electrical Erosion

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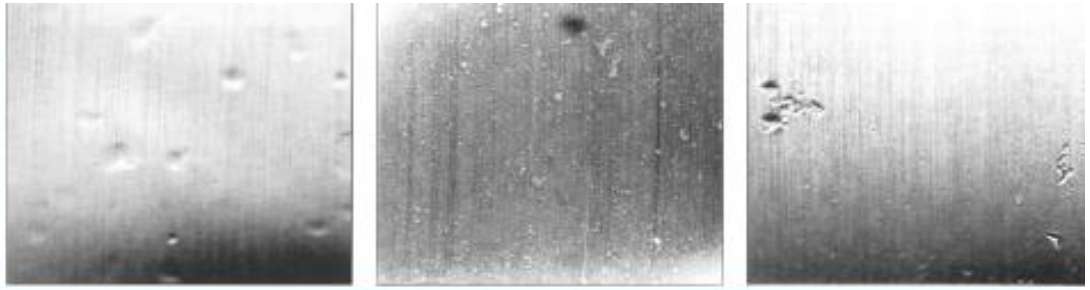
Bearings – Failure mode classification according to ISO 15243



1. Fatigue
2. Wear
3. Corrosion
4. Electrical erosion
5. Plastic deformation
6. Fracture

- localised overloading
- over-rolling of particles : dents
- soft / hardened steel / hard mineral

5.1. Overload

5.2 Indentation from debris

5.3 Indentation by handling

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Bearings – Failure mode classification according to ISO 15243

1. Fatigue
2. Wear
3. Corrosion
4. Electrical erosion
5. Plastic deformation
6. Fracture
   - 6.1. Forced fracture
   - 6.2. Fatigue fracture
   - 6.3. Thermal cracking

- stress concentration > tensile strength
- impact / overstressing

LUBRICATION – A BRIEF NOTE

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LUBRICATION

A lubricant is primarily used to minimise friction by providing an incompressible fluid ‘film’ between opposiing surfaces.
This may manifesti itself as a continuous film (as in plain bearings) or as a fluid ‘wedge’ that forms ahead of roller bearings.

CONFLICT?

All lubricants become less viscous as they warm up. A lubricant that is thin enough to be effective at a cold start from standstill without producing too much friction will be less able to provide good film strength at the higher temperature range. This is the compromise.

CLEANING

Wear between gears is inevitable, so it is important that the material worn away from the surface of a gear is carried away, thus minimising the chance that such particles will accelerate the wear within a gearbox.

COOLING

Cooling – warms up and carries heat away from gears enabling the temperature within the gearbox to be kept within optimal operating limits.

OTHER ISSUES

Foaming – When a gas is introduced into an oil, it becomes far more ‘compressible’ – leading to a drastic reduction in film strength and a huge drop in protection for bearing surfaces.

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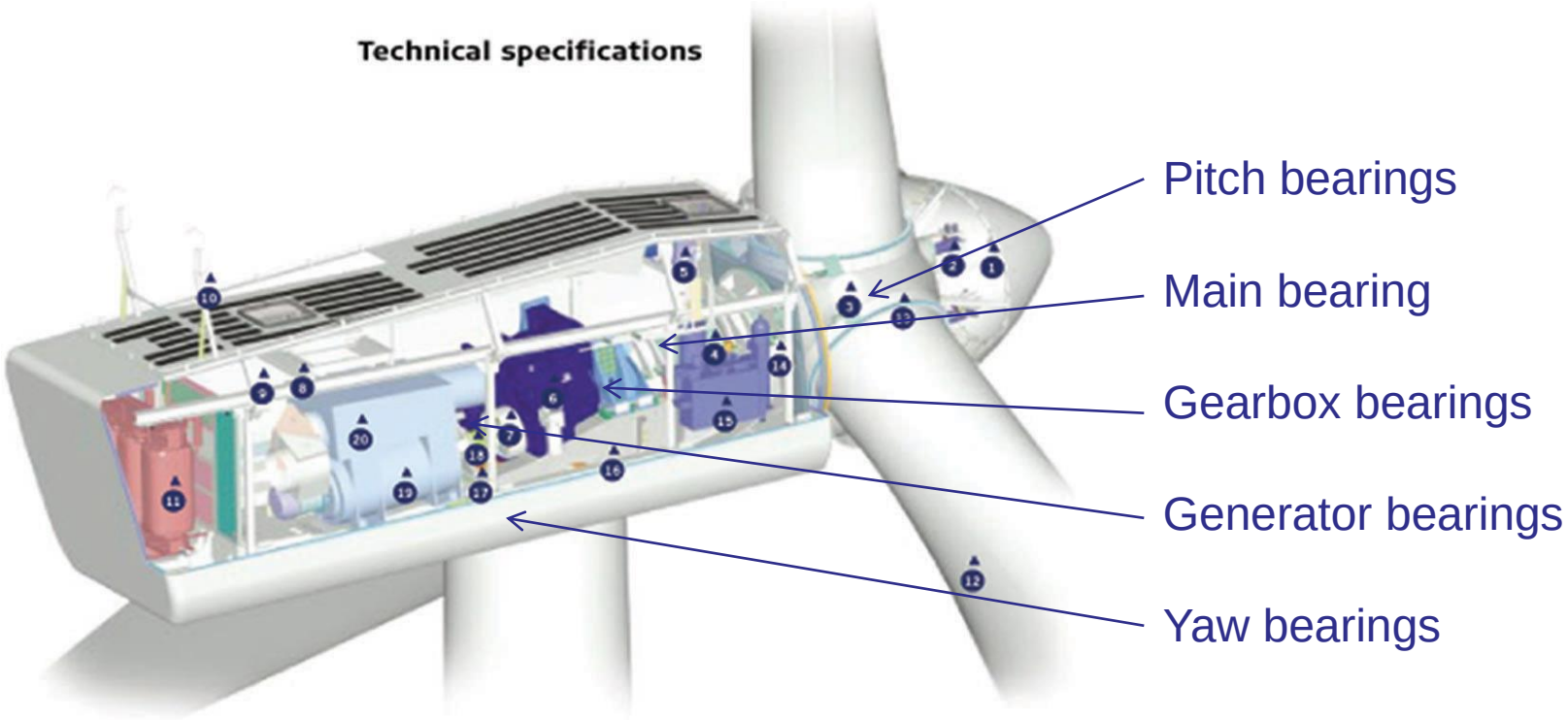
Bearings in a typical Wind Turbine



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Claims Perspective

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Bearing Failure Losses : CONSIDERATIONS

- **Anticipated life of a component vs Age at failure**
- **Operation and Maintenance regime**
- **Operating Environment**
- **Preservation of Evidence**
- **Number of Failures – Series Loss?**
- **‘Known Issues’ within this WTG fleet?**

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Wordings and Conditions

Wording – Coverage / extend of cover

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CAR

The insurer shall indemnify the insured for any **sudden physical loss of or damage to** the property insured which the insured could not **reasonably have foreseen** and which occurs within the territorial limits at any time during the period of insurance **due to any cause not specifically excluded** and which results in property insured needing to be repaired or replaced.

OAR

The insurance shall cover any material damage to the insured WTG as a result of **any sudden and unforeseen occurrence** arising out of any cause subject to the exclusions referred to in condition X below and the conditions stated.
The insurance shall also cover any loss or **damage occurring during servicing.**
Cover under the insurance shall be subject to the WTG having been fully installed on the premises insured, tested and delivered in a satisfactory way.

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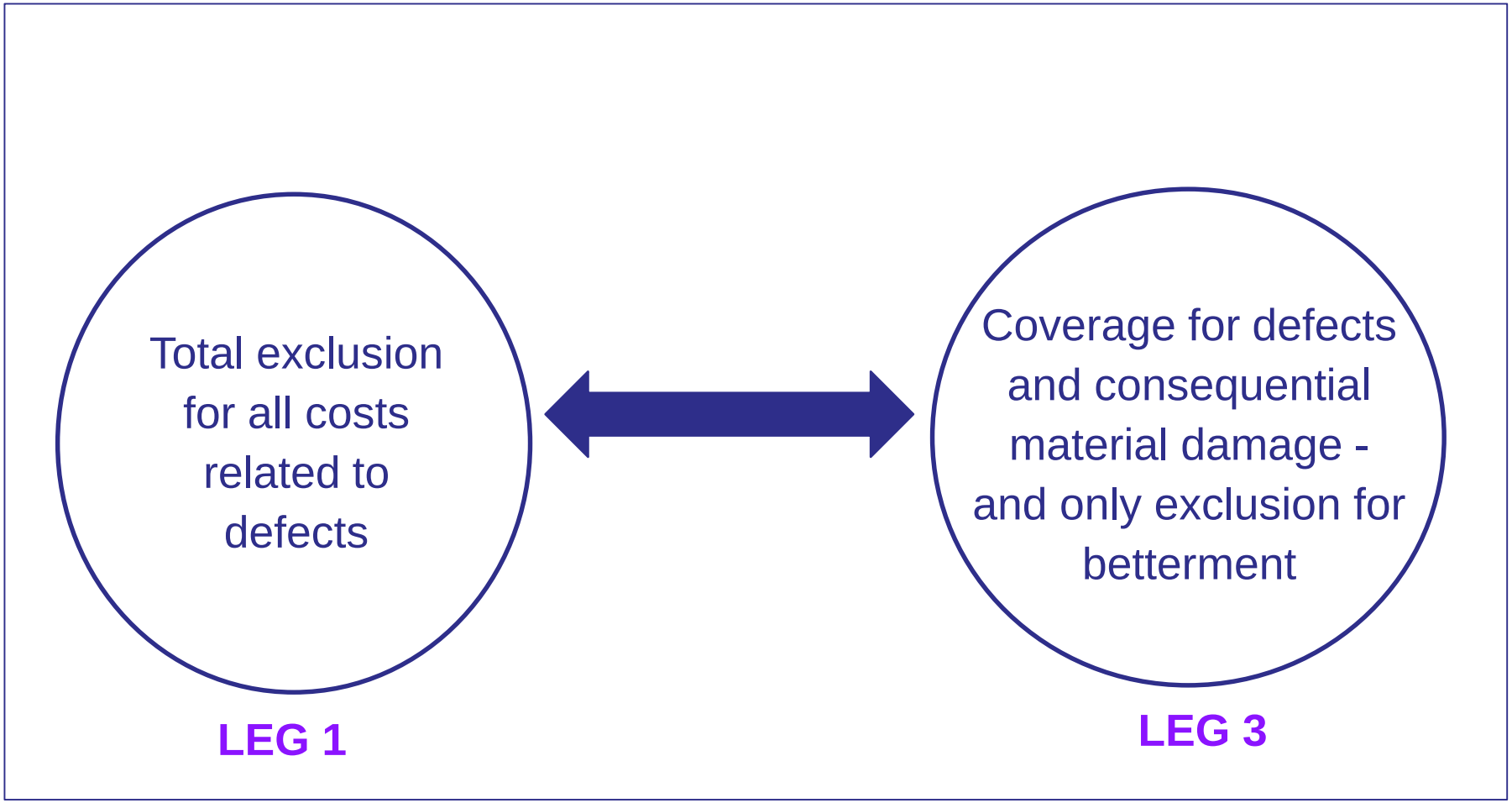
BEARING FAILURE LOSSES
COMMON CLAUSES: **LEG** (London Engineering Group)



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Bearing Failure Losses: COMMON CLAUSES

WelCAR / WindCAR Defective Part Exclusion Clause

The insurance afforded by Section I covers physical loss and/or physical damage to the property insured herein occurring during the Policy Period and resulting from a Defective Part, faulty design, faulty materials, faulty or defective workmanship or latent defect even though the fault in design may have occurred prior to the attachment date of the Policy.
Section I, however, does not provide coverage for loss or damage to (including the cost of modifying, replacing or repairing) any Defective Part itself, unless all of the following are satisfied:

a. such Defective Part has suffered physical loss or physical damage during the Policy Period;
b. such physical loss or physical damage was caused by an insured peril external to that part; and
c. the defect did not cause or contribute to the physical loss or physical damage.

In no case shall Section I provide coverage for any cost or expense incurred by reason of betterment or alterations in design.

Wording – Wear and Tear Exclusion

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normal

normal

CAR

loss or damage resulting from **wear and tear, corrosion, oxidation or deterioration** of property insured, but this exclusion shall be limited to the parts immediately affected and shall not extend to liability for loss of or damage to parts of the property insured lost or damaged as a consequence thereof;

normal

normal

OAR

- **wear and tear, rust, corrosion and other gradual deterioration** and/or breakdown as well as technical deterioration,
- events which are solely attributable to **malfunctions,**

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BEARING FAILURE LOSSES
COMMON CLAUSES: Warranty Exclusion

TAKE CARE

Warranty and Guarantee Exclusion

OAR
The Insurance does not cover loss or damage for which a supplier, repairman, carrier or other party can be held liable under contract, guarantee commitments, legislation or case law.

CAR
Be aware;
Munich Re – Comprehensive Project insurance – E 347.2-E does not have any specific exclusion for warranty or guarantee obligations.

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BEARING FAILURE LOSSES
COMMON CLAUSES: Serial Loss

Wording – Serial loss

Routinely included in standard CAR and OAR insurances, especially for big windfarms or when insuring Manufacturers

Considerations:

- Scale of problem
- Is the scaling applicable to both Property Damage and BI?
- How are deductibles / waiting periods is applied?
  Single or Multiple deductibles?

Example
Insurers shall indemnify the Insured in respect of direct physical loss or direct physical damage **of the same nature** to any Wind Turbine Generator **after application of deductible to each claim** according to the following scale:
100% of the first three, 75% of the next three, 50% of the next three and 0% from number ten onwards

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Bearing Failure Losses : CONSIDERATIONS - Recap

- **Anticipated life of a component vs Age at failure**
- **Operation and Maintenance regime**
- **Operating Environment**
- **Preservation of Evidence**
- **Number of Failures – Series Loss?**
- **‘Known Issues’ within this WTG fleet?**

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BEARING FAILURE LOSSES

Open Questions

If a component fails early:

- Can it be considered Defective?
  - It has not achieved its design lifespan
  - The average life of that component across the ‘fleet’ is much higher
- Can it be considered to be ‘Worn Out’?
  - All the signs point towards wear as the primary cause
  - No defects or shortcomings were found in associated systems (control, lubrication, cooling, protection)

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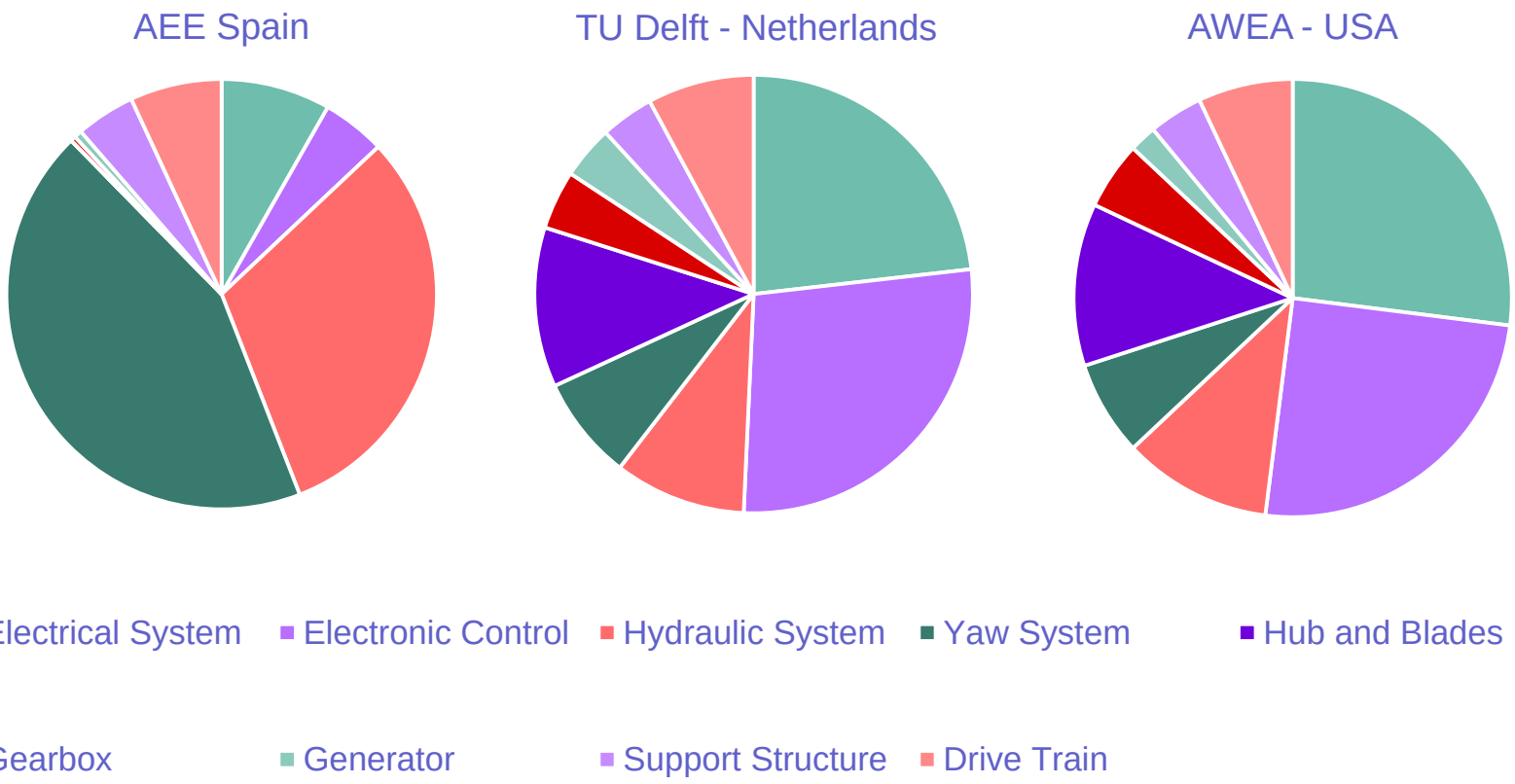
BEARING FAILURE LOSSES

Food for Thought

Comparative Component Failure Rates – Onshore Wind Farms:
Annual figures published by National Bodies



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Summary

Bearing Failure in Offshore Wind Turbines. (From Codan´s portfolio)

Bearings are a factor in 1.9% of all CAR losses

But

They are a factor in 21.0% of all OAR losses...

Accurate classification of bearing damage can assist in quick decisions regarding coverage, however that is not the end of the story – we have an obligation to support the industry by spotting and addressing early trends and advising on Risk Control strategies.
In sharing loss experience we can contribute to the industry-wide drive to reduce the LCOE (Levelised Cost of Energy) for Offshore Wind.

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Summary

- **Summary of points and open questions**
- **Damage to Bearings now classified by ISO coding that eliminates some debate over the precise cause of damage**
- **These pointers can also help us determine the earliest (and therefore proximate) root cause for bearing damage**
- **The key applicable common clauses and wordings to be considered**
- **Component lifetimes are established, and how they can vary**
- **Food for thought in terms of how predicted lifetime for a component can be less than helpful**
- **Thanks for listening**

THANK YOU

&

Over to David Phillip