Premature bearing failures in wind turbine gear units

Drivers and counter measures
Early cracks have occurred commonly within the first 1-3 years of operational time, or at less than 10% of the calculated rating life.
Crack appearance depending on heat treatment

Through hardened as well as case carburized can fail!

Martensite
+50 to +100 MPa
Tensile at surface

Bainite
−50 to −100 MPa
Compressive at surface

Case carburized
−100 to −200 MPa
Compressive at surface
White etching cracks – a symptom of bearing failures

White etching areas are created around cracks due to crack face rubbing

White etching areas are a symptom of the failure and not the root cause

Focus should be on understanding the drivers and counter measures of the premature failures

• Why are cracks initiated much faster in premature failing bearings?
• How to make bearing system more robust?

White etching crack in large TRB rolling contact fatigue test
Premature bearing failures: understanding the drivers

- Rolling contact fatigue
  - ‘Cyclic’ stresses and loading
    - Tensile stresses
    - Short heavy loads
    - Dynamics/vibrations
  - Premature failures ‘Accelerated’ fatigue
    - ‘Stresses’ higher than anticipated
    - ‘Strength’ lower than anticipated
  - Tribology/hydrogen aspects
    - Environmental weakening
      - Electrical currents
      - Corrosion/water
      - Lubricant influence; mixed friction and slip
SKF test results – Tensile stresses

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SKF test results – Short heavy loads and dynamics/vibrations

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SKF test results – Electrical currents

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SKF test results – Corrosion/water

Rolling contact fatigue

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- Dynamics/vibrations

Tensile stresses
Short heavy loads
Dynamics/vibrations
Electrical currents
Corrosion/water
Lubricant influence; mixed friction and slip
SKF test results – Lubricant influence

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Understanding premature failures

White etching areas (WEA) in white etching cracks are a consequence not a root cause!

- Cracks come first, then WEAs
- WEAs are created by crack phase rubbing (possibly supported by chemical effects when lubricant enters)

Drivers for premature failures are identified and supported by test results:

- **Local stresses** (short time high loads, structural stresses)
- **Environmental weakening** (mixed friction & lubrication influence, moisture corrosion, stray currents)
Each failure is “unique”

- The exact combination of influencing factors that explain the failures in different bearing positions in wind gear units is not yet understood.
- “The root cause” does not exist and each failure case needs to be reviewed in the light of the corresponding operating conditions.
- However countermeasures can be identified to counter the known drivers.
# Overview of counter measures

<table>
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<tr>
<th>Drivers</th>
<th>Bearing system</th>
<th>Bearing</th>
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</table>
| “Stresses” higher than anticipated  
(Tensile stress, short heavy loads) | • Bearing arrangement  
• Bearing support  
• Limit housing deformations  
• Clearance / preload setting  
• Verify loads extreme events (incl. grid events) | • High compressive residual stresses  
• Cleaner steel |
| Environmental weakening  
(Corrosion, electrical current, mixed friction and lubricant) | • Limit water in oil  
• Limit humidity during standstill  
• Transport and mounting  
• Avoid stray current  
• Limit vibrations | • SKF Black Oxide  
• Case carbonitriding  
• VC444 (very high costs)  
• Insocoat, hybrid bearings (related to electrical erosion) |
Advantages of SKF black oxide

- Improves running-in properties and reduces friction
- Improved resistance against smearing damage
- Better performance in low lubrication conditions
- Reduced risk of chemical attack from aggressive oil additives on the bearing steel
- Increased oil and grease adhesion
- Enhanced corrosion resistance
- Reduced chance of hydrogen generation & permeation in the bearing steel
Strong field experience with SKF black oxide

More than 140,000 SKF black oxide bearings supplied to the gearbox market

- With significant volumes since 2008
- Largely applied on CRB, however possible for all bearing types
- 99% through hardened rings and rollers
- On all positions in gearbox
- Applied in all turbine sizes
- Supplied in various sizes

To date SKF black oxide has no known “serial” issue with premature failures (< 50 ppm)