White Etching Cracks (WEC)
How to reduce WEC in Wind turbines
What is White Etching Cracks (WEC)?

WEC are material changes that can occur in rolling bearing steels and have significantly higher hardness than the original structure. Under mechanical load, cracks may develop between the white, hard areas and the matrix that, under strain, propagate to the surface and lead to failure. These cracks occur in both through hardened and case hardened rolling bearings.

How do WEC occur?

Schaeffler has comprehensive testing facilities for assessing the influences and developing solution concepts for reducing the risk of WEC.

According to our current level of knowledge, WEC occur only as a result of unspecified additional loads (such as electricity, dynamics, mixed friction) that supplement the usual bearing loads and not to a root cause in the bearing itself or in the bearing design.

Influences, which could have an effect on component fatigue, such as contact pressure, an insufficient level of steel purity or overloading, do not cause the occurrence of WEC.
How to reduce WEC in wind turbines

Summary: Schaeffler solutions

Through hardened bearings with Durotect® B

Schaeffler recommends Durotect® B (black oxide coating)

- Good protection against WEC
- Longest and best field experience: failure rate 0,02%
  - 482,000 Bearings, < 100 Failures in the past 9 years
- Economical solution
- Durotect® B also minimizes the risk of damage caused by slippage, improves running-in behavior and provides protection against corrosion

The WEC risk can be limited by the design of the bearing and the selection of lubricants or materials.

Lubrication advise

- Oil changes: keep the oil history clean and document the oil changes
- Avoid water in lubricant as far as possible.

Further Schaeffler solutions

Special carbonitriding steel Mancrodur® with Durotect® B
High chromium special steel Cronidur® 30
White Etching Cracks (WEC)
Crack networks including white etching flanks
A type of White Etching Area WEA
→ Nital etching: phase that do not corrode, appear white

Related designations:
White structure flaking
Brittle crack network
Axial Cracks (referring to damage appearance at martensitic steels)

Other White Etching Areas (WEA)

White etching layer WEL
White Bands
Related to classic fatigue
Butterfly
White flanks around non metallic inclusions
What is White Etching Cracks (WEC)?

**Affected Applications**

WEC occurs in many sectors of Industry including Automotive

WEC occurs in all bearing components, except cages

- independent from line or point contact
- independent from bearing type
- independent from material (except Cronidur)
- independent from heat treatment

WEC failures are not unique to wind turbines. There are many other applications that have experienced problems related to WEC.
What is White Etching Cracks (WEC)?

Affected Applications in wind turbines

**Rotor shaft**
- Spherical roller bearings
- Tapered Roller bearings

**Gearbox**
- Cylindrical roller bearings
- Tapered Roller bearings in Planet Gears
- Intermediate speed shaft
- High speed shaft
How to reduce WEC in wind turbines

How do White Etching Cracks occur?

<table>
<thead>
<tr>
<th>Additional Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
</tr>
<tr>
<td>Mixed Friction</td>
</tr>
<tr>
<td>Dynamics</td>
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</tbody>
</table>

lead to

WEC

influences

reduce the risk of

- Reduce electrostatics and current flows
- Reduce mixed friction as far as possible
- Reduce vibrations
- Reduce traction slippage
- Prevent unfavourable bearing kinematics

Preventive Measures
How to reduce WEC in wind turbines

How do White Etching Cracks occur?

Preventive Measures

The risk of WEC can be reduced if various points are observed in design of the bearing arrangement and the selection of lubricants and materials.

<table>
<thead>
<tr>
<th>Preventive Measures</th>
<th>Additional Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduce electrostatics and current flows</strong></td>
<td><strong>Electricity</strong></td>
</tr>
<tr>
<td>Optimise grounding concept (coupling design, insulating coatings, ...), quality/concept of drive (windings) and control/inverter</td>
<td><strong>Mixed Friction</strong></td>
</tr>
<tr>
<td>Identify electrostatic sources: belt drives, rotor blades, paper roll contact, flowing liquids. Take appropriate measures</td>
<td><strong>Dynamics</strong></td>
</tr>
<tr>
<td><strong>Reduce mixed friction as far as possible</strong></td>
<td><strong>lead to</strong></td>
</tr>
<tr>
<td>Pay attention to lubrication conditions</td>
<td><strong>WEC</strong></td>
</tr>
<tr>
<td>Prevent mixed friction (k &lt; 1)</td>
<td><strong>influences</strong></td>
</tr>
<tr>
<td>Ensure low roughness of element at risk of failure (normally inner ring)</td>
<td><strong>in combination with auxiliary loads</strong></td>
</tr>
<tr>
<td>Avoid excessively high viscosities (k &gt; 10) at high (n \cdot d_M) values</td>
<td></td>
</tr>
<tr>
<td>Ensure sufficient oil release from greases</td>
<td><strong>reduce the risk of</strong></td>
</tr>
<tr>
<td><strong>Reduce vibrations</strong></td>
<td></td>
</tr>
<tr>
<td>Avoid high axial and rotational accelerations</td>
<td>Preload/low operating clearance as far as possible</td>
</tr>
<tr>
<td>Ensure low roughness of element at risk of failure (normally inner ring)</td>
<td>Specific load (\frac{F_r}{C_0}) not too low or difference from minimum load not too large</td>
</tr>
<tr>
<td>Avoid excessively high viscosities (k &gt; 10) at high (n \cdot d_M) values</td>
<td>Keep differential and spin slippage low</td>
</tr>
<tr>
<td>Ensure sufficient oil release from greases</td>
<td>Use design with optimised traction slippage</td>
</tr>
<tr>
<td><strong>Reduce traction slippage</strong></td>
<td></td>
</tr>
<tr>
<td>Achieve preload/low operating clearance as far as possible</td>
<td></td>
</tr>
<tr>
<td>Specific load (\frac{F_r}{C_0}) not too low or difference from minimum load not too large</td>
<td></td>
</tr>
<tr>
<td>Keep splash losses low (avoid high oil flows, large outlet holes)</td>
<td></td>
</tr>
<tr>
<td>Pay attention to skewing (tapered roller bearings, cylindrical roller bearings)</td>
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</tr>
</tbody>
</table>
How to reduce WEC in wind turbines

Recommended Schaeffler Solution: Through hardened + Durotect® B

Through hardened bearings with Durotect® B

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What is Durotect® B?
The coating system Durotect® B has been consistently developed from conventional black oxide finishes to give increased performance.

Advantages
Durotect® B…
- minimizes the risk of damage caused by slippage
- improves running-in behavior
- provides protection against corrosion
- increases the level of robustness to WEC independent from base material

Schaeffler therefore always recommends its customers to use gearbox bearing supports in Durotect® B.

Features
- Coating comprising mixed iron oxides
- Colour: dark brown to deep black

Schaeffler’s Surface Technology Competence Center has developed an ideal coating system to reduce/eliminate WEC damage.
How to reduce WEC in wind turbines

Recommended Schaeffler Solution: Through hardened + Durotect® B

Field track record
It has been proven statistically that black oxide finishing of outer and inner rings as well as rollers significantly reduces the formation of white etching cracks.

Longest and best field experience: failure rate 0,02%
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Recommended Schaeffler Solution: Through hardened + Durotect® B

Field track record
Longest and best field experience: failure rate 0.02%
482,000 Bearings, < 100 Failures in the past 9 years

Statistics in relation to 482,000 bearings (delivered 2005 – 2014)

<table>
<thead>
<tr>
<th>Bearing location in wind gearboxes</th>
<th>Planet bearings</th>
<th>45 %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High speed shaft bearings</td>
<td>35 %</td>
</tr>
<tr>
<td></td>
<td>Intermediate speed shaft bearings</td>
<td>20 %</td>
</tr>
<tr>
<td>Heat treatment (all bearings are through hardened)</td>
<td>Martensitic</td>
<td>55 %</td>
</tr>
<tr>
<td></td>
<td>Bainitic</td>
<td>45 %</td>
</tr>
<tr>
<td>Bearing type</td>
<td>Cylindrical roller bearings</td>
<td>80 %</td>
</tr>
<tr>
<td></td>
<td>Tapered roller bearings</td>
<td>20 %</td>
</tr>
<tr>
<td>Lubricants (In general the 482,000 bearings are operated in all common lubricants used in wind gearboxes. This is our experience in terms of prevalence of wind oils.)</td>
<td>Mobil SHC XMP 320</td>
<td>70 %</td>
</tr>
<tr>
<td></td>
<td>Castrol Synthetic X 320</td>
<td>20 %</td>
</tr>
<tr>
<td></td>
<td>Castrol Synthetic A 320</td>
<td>5 %</td>
</tr>
<tr>
<td></td>
<td>Texaco Meropa 320</td>
<td>5 %</td>
</tr>
<tr>
<td>Failure free running time</td>
<td>maximum time: 9 years, average time: 4 years</td>
<td></td>
</tr>
</tbody>
</table>