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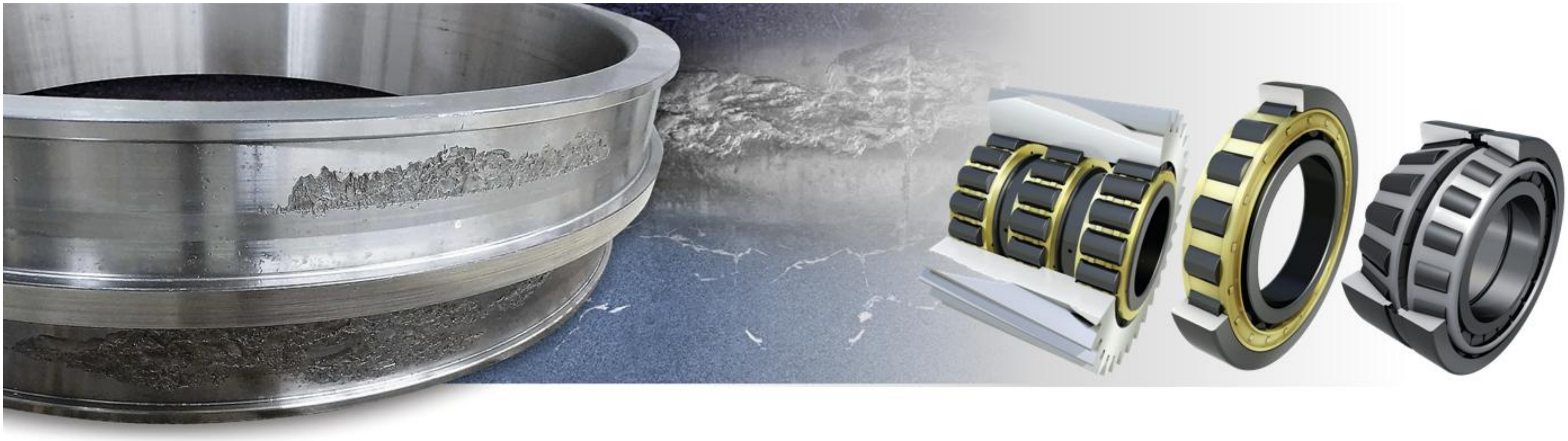

White Etching Cracks (WEC)

How to reduce WEC in Wind turbines

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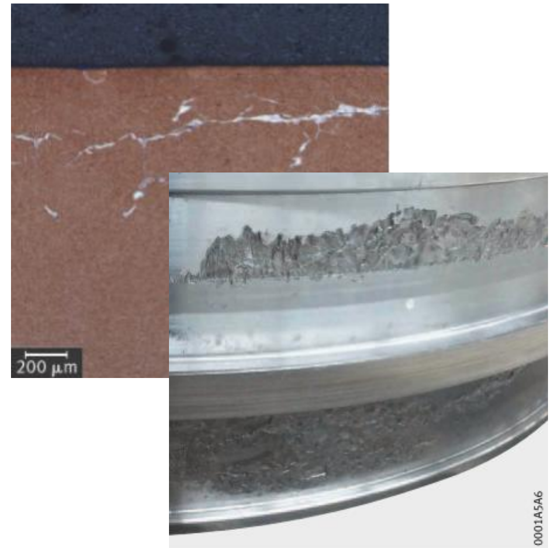
Summary: WEC and cause for WEC

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.

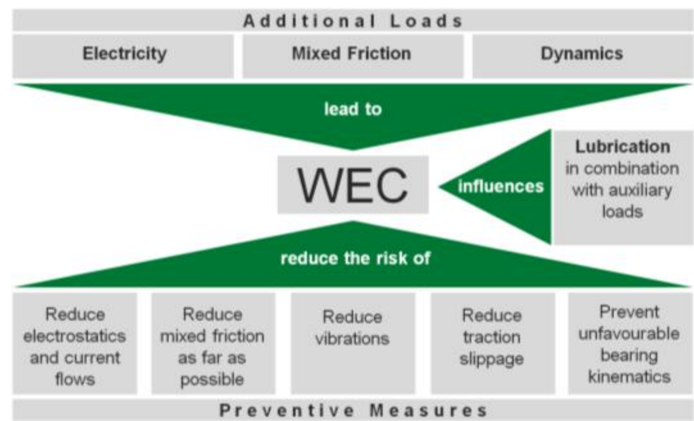


How do WEC occur?

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.



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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

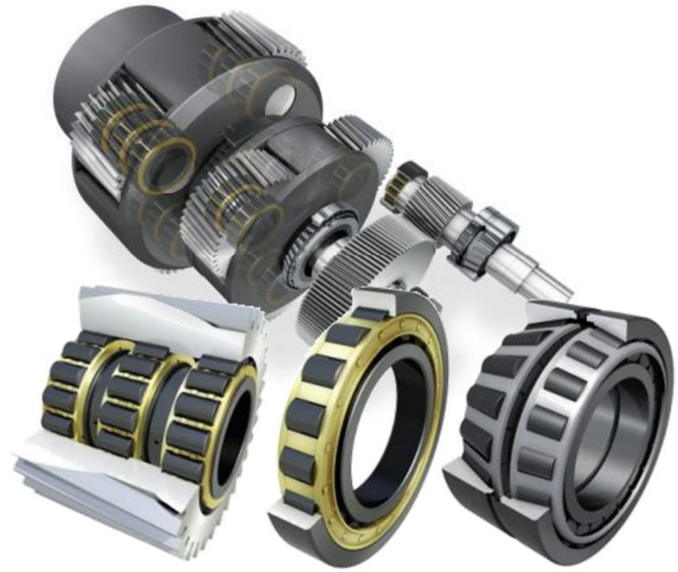
The WEC risk can be limited by the design of the bearing and the selection of lubricants or materials.

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

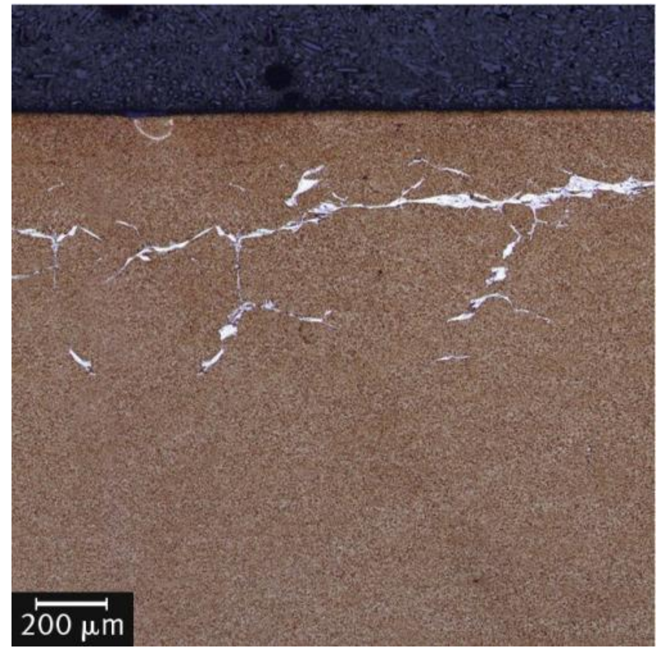
Special carbonitriding steel Mancrodur® with Durotect® B
High chromium special steel Cronidur® 30



What is White Etching Cracks (WEC)?

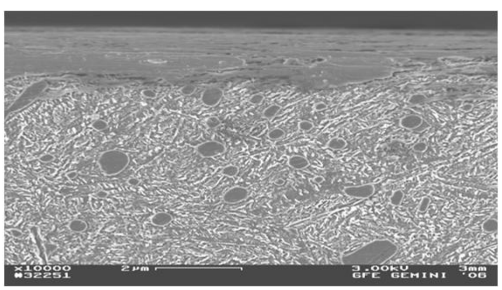
White Etching Cracks (WEC)
Crack networks including white etching flanks
A type of White Etching Area WEA
→ Nital etching: phase that do not corrode, appear white

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

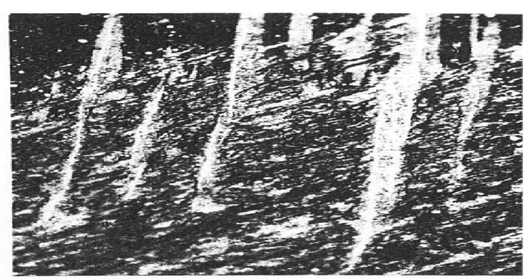


Other White Etching Areas (WEA)

White etching layer WEL



White Bands
Related to classic fatigue



Butterfly
White flanks around non metallic inclusions

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What is White Etching Cracks (WEC)?

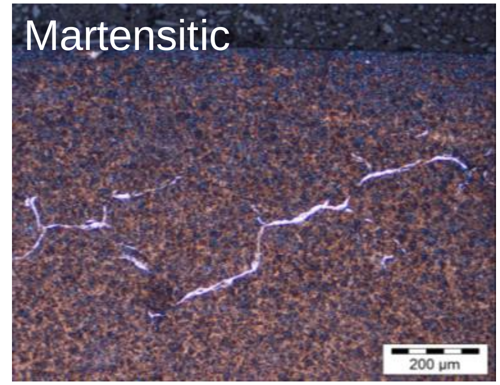
<u>Affected Applications</u>

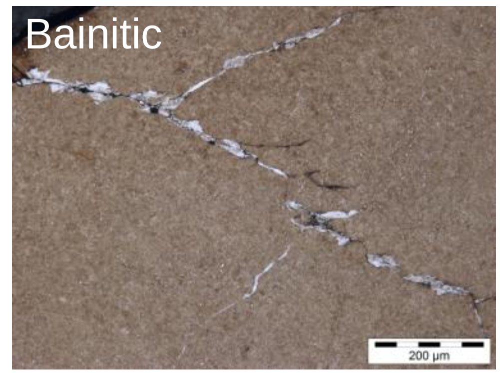
WEC occurs in many sectors of Industry including Automotive

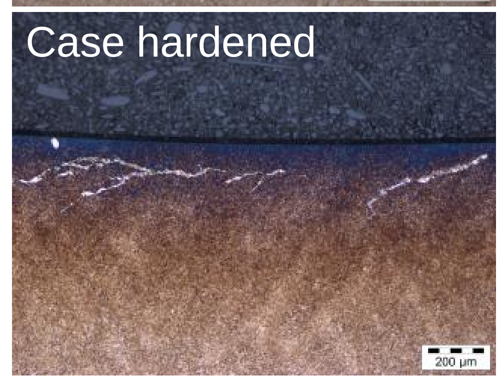
WEC occurs in all bearing components, except cages

- **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.

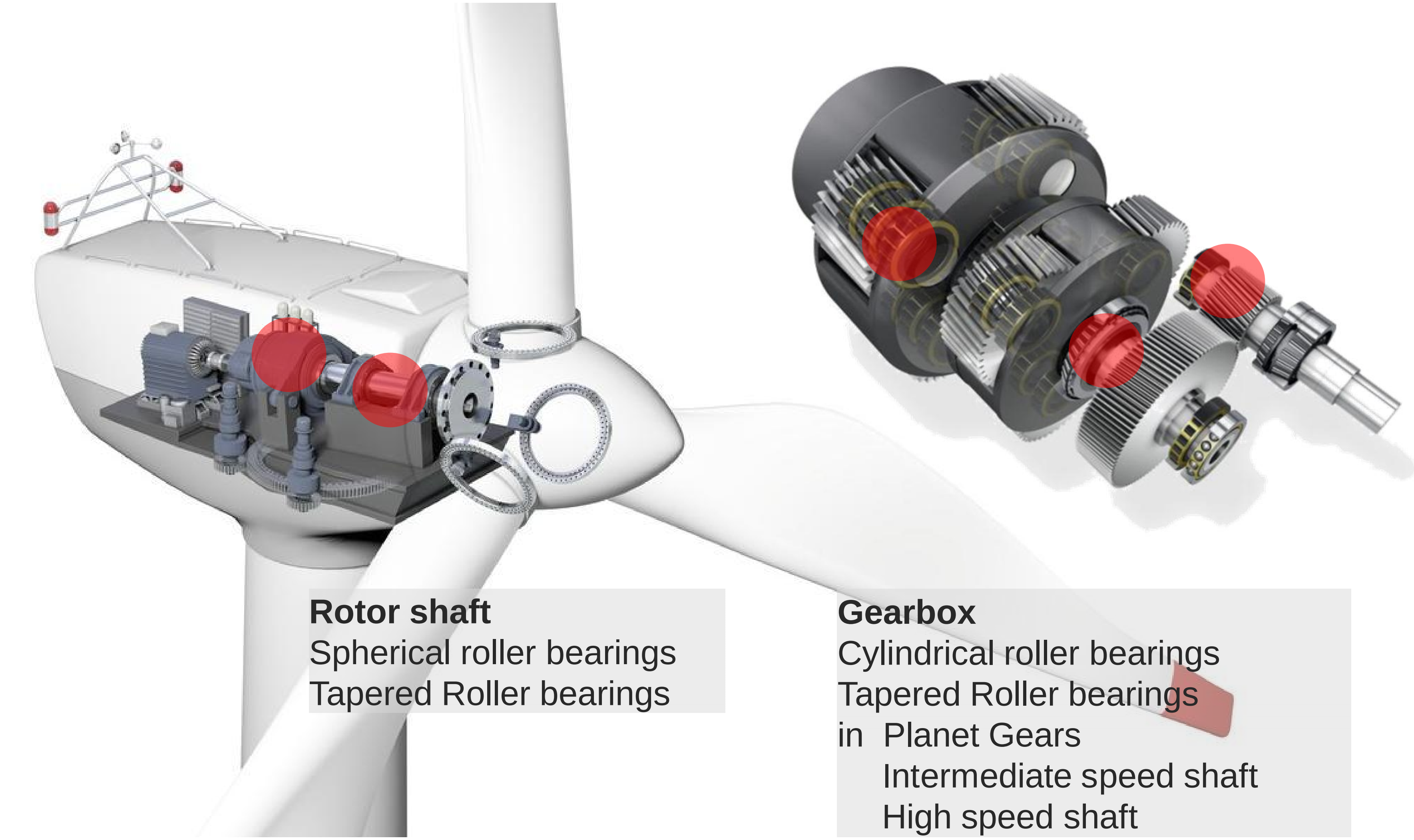






What is White Etching Cracks (WEC)?

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

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How do White Etching Cracks occur?

Additional Loads

Electricity	Mixed Friction	Dynamics

lead to

WEC

influences

Lubrication in combination with auxiliary loads

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 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.

reduce the risk of

Reduce electrostatic and current flows

Optimise grounding concept (coupling design, insulating coatings, ...), quality/concept of drive (windings) and control/inverter

Identify electrostatic sources: belt drives, rotor blades, paper roll contact, flowing liquids. Take appropriate measures

Reduce mixed friction as far as possible

Pay attention to lubrication conditions

Prevent mixed friction ($\kappa < 1$)

Ensure low roughness of element at risk of failure (normally inner ring)

Avoid excessively high viscosities ($\kappa > 10$) at high $n \cdot d_M$ values

Ensure sufficient oil release from greases

Reduce vibrations

Avoid high axial and rotational accelerations

Reduce high frequency vibrations (> 100 Hz)

Reduce traction slippage

Achieve preload/low operating clearance as far as possible

Specific load (F_r/C_0) not too low or difference from minimum load not too large

Keep splash losses low (avoid high oil flows, large outlet holes)

Use design with optimised traction slippage

Prevent unfavourable bearing kinematics

Select optimum bearing type for friction kinematics: low pv value

Keep differential and spin slippage low

Pay attention to skewing (tapered roller bearings, cylindrical roller bearings)

Recommended Schaeffler Solution: Through hardened + Durotect® B

Through hardened bearings with Durotect® B

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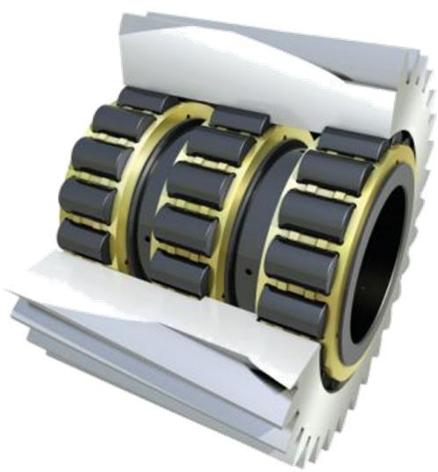

Recommended Schaeffler Solution: Through hardened + Durotect® B

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.

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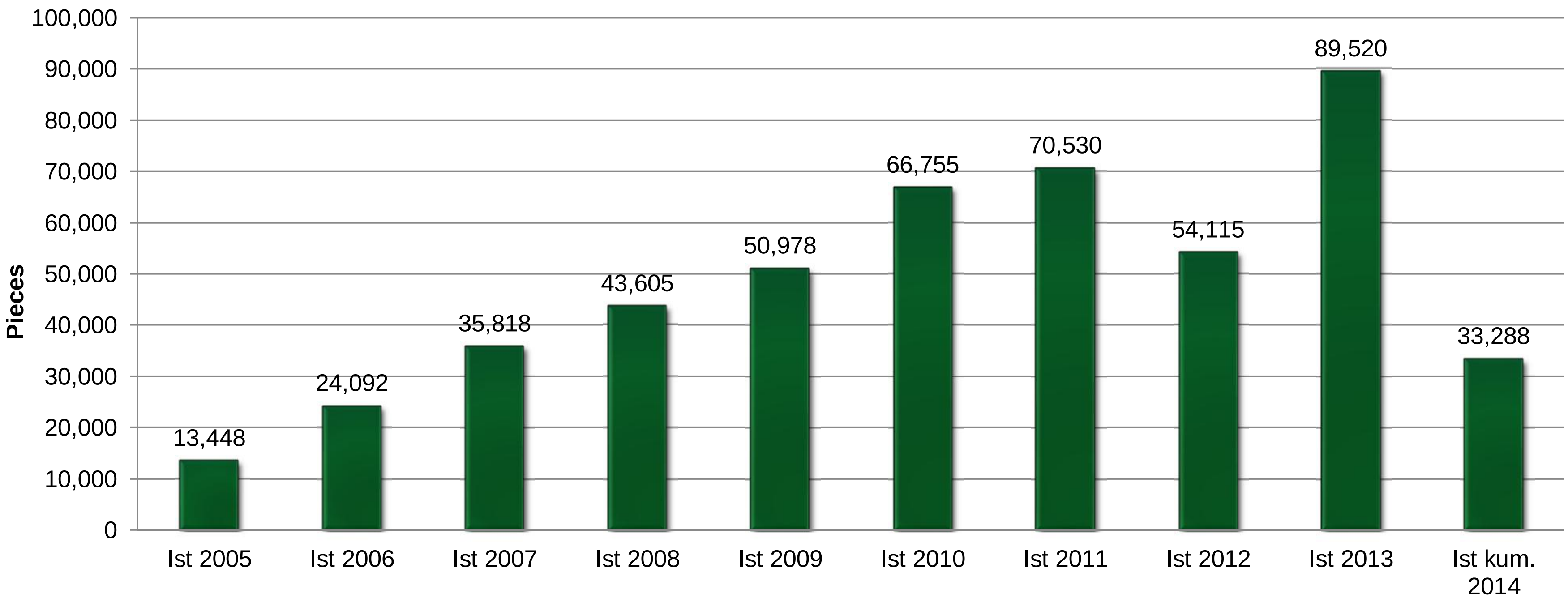
Recommended Schaeffler Solution: Through hardened + Durotect® B

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%
482.000 Bearings, < 100 Failures in the past 9 years



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Recommended Schaeffler Solution: Through hardened + Durotect® B

Field track record

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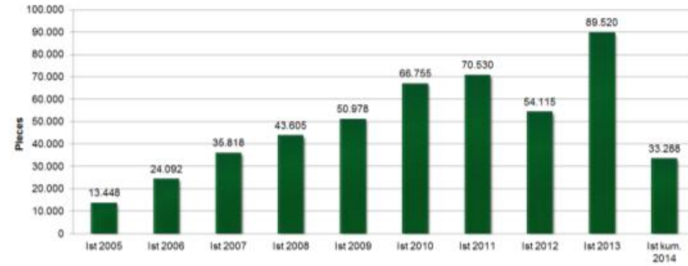

Statistics in relation to 482.000 bearings (delivered 2005 – 2014)		
Bearing location in wind gearboxes	**Planet bearings**	**45 %**
	High speed shaft bearings	**35 %**
	Intermediate speed shaft bearings	**20 %**
Heat treatment (all bearings are through hardened)	**Martensitic**	**55 %**
	Bainitic	**45 %**
Bearing type	**Cylindrical roller bearings**	**80 %**
	Tapered roller bearings	**20 %**
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.)	**Mobil SHC XMP 320**	**70 %**
	Castrol Synthetic X 320	**20 %**
	Castrol Synthetic A 320	**5 %**
	Texaco Meropa 320	**5 %**
Failure free running time	**maximum time: 9 years, average time: 4 years**	

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