Research on White Etch Crack Failures and Failure Prevention

Presented at AWEA Windpower 2015
May 21st, 2015
Rob Budny
President, RBB Engineering
rob@rbbengineering.com
805-280-9044
Topics Covered

• Definition of Terms
• Prevalence of WEC Failures
• WEC Failure Morphology
• Case Study of Intermediate and Main Bearing Failures in a Large Fleet of Utility Scale Wind Turbines
  • Bearing Information
  • Failure Rates
  • Failure Investigation Results
  • Conclusions
• Current Research
• Resource for Additional Information
**Definition of Terms**

- **White Etch Cracking (WEC):** A term that has become commonly accepted to describe bearing failures that result from a non-classical fatigue mechanism. The failures are associated with the development of Irregular White Etch Areas (irWEA) and White Etch Cracks (WEC) in the sub-surface of the bearing.

- **Axial Cracking, White Structure Flaking:** Alternative terms for WEC failures.

- **White Etch Area (WEA):** A broad category of microstructural alterations known to occur in bearings (white structure layer, butterflies, white etching bands).

- **Irregular White Etch Area (irWEA):** A particular type of White Etch Area associated with WEC failures. irWEA have an irregular shape that distinguishes them from other types of white etch areas.

- **White Etch Cracks:** Cracks that develop in the sub-surface of the bearing, near irWEA. The cracks eventually propagate to the surface, resulting in formation of macropits and bearing failure.

- **Austenite:** Austenite is one of the phases of steel. It is softer than other phases (such as martensite and bainite) but it is also tougher, and is known to increase the fatigue life of carburizing steels.

© Copyright 2015, RBB Engineering LLC
Prevalence of WEC Failures

- Up to half of all wind turbine gearbox failures are due to WEC

*Data Source: NREL GRC Failure Database
First indication of a WEC failure is development of axial crack on bearing inner ring.

Over rolling of the cracks results in formation of macropits.

With sufficient continued operation, entire roller path will develop macropits, and bearing will become non-functional.
irWEA Appearance

irWEA, Specimen Light Etch

irWEA, Specimen Heavy Etch
Case Study Details

- Fleet size: Over 500 turbines
- Turbine Size: Utility Scale, Multi-megawatt
- Operating Hours: Fleet leaders had up to 50,000 operating hours
- Bearing Positions Affected: Intermediate Speed and Low Speed
- Intermediate Speed Bearing Type: Cylindrical Roller Bearing (CRB)
- Intermediate Speed Bearing Manufacturers: Vendor “A” and Vendor “B”, roughly 50/50 split between bearing vendors, similar operating hours
- Low Speed Bearing Type: Taper Roller Bearing (TRB)
- Low Speed Bearing Manufacturers: Vendor “C” and Vendor “D”, roughly 50/50 split between bearing vendors, similar operating hours
Axial Cracks and irWEA on Intermediate Bearing IR

Intermediate Bearing Axial Cracks

Intermediate Bearing irWEA
Vendor A and Vendor B bearings both NJ 2334. Identical number of rollers, roller length, similar roller crown.

Vendor A, 0.2% failure rate, no WEC. Vendor A bearings case carburized.

Vendor B, 16% failure rate, all failures due to WEC. Vendor B bearings through-hardened.
Mainshaft Bearing Inner Ring Macropits

Mainshaft Bearing Inner Ring irWEA
Vendor C and Vendor D bearings both special TRB’s, both case carburized. Similar number of rollers, roller length, different crown geometry (Vendor C circular crown, Vendor D “aerospace crown“)

- Vendor “C”, 0% failure rate, no WEC
- Vendor “D”, 17% failure rate, all failures due to WEC
Conclusions From Case Study

• **Intermediate Bearings:**
  - Half of the population used through-hardened bearings, half used case carburized bearings
  - Bearings were otherwise extremely similar
  - The case carburized bearings had much higher levels of both compressive residual stress and retained austenite
  - The failure rate of the case carburized bearings was 0.2%, failure rate for through hardened bearings 16%

• **Main Bearings:**
  - All of the bearings were case carburized, but there was a difference in microstructure
  - Half of the population used bearings with up to 27% retained austenite, half used bearings with up to 17% retained austenite
  - Bearings with higher level of retained austenite did not fail, those with lower levels had a failure rate of 17%

• **Conclusions:**
  1. Case carburized bearings are less likely to fail from WEC than are through-hardened bearings
  2. Higher levels of retained austenite appear to increase resistance to WEC failures
• The details of this case study were published in a peer reviewed journal and have attracted considerable interest

• There has been resistance on the part of many bearing companies to adopt the recommendations made in the paper:
  • In locations that are prone to WEC failures, use case-carburized inner rings
  • Maintain levels of RA above 20%

• Many of the bearing companies have promoted alternative solutions:
  • Black oxide coatings
  • Bainitic heat treatment
  • Alternative steel (Cronidur 30)

• Some academic and government labs are testing the effect of retained austenite on WEC formation
  • Argonne National Labs
  • University of Akron
Researchers at NSK published figure above showing large increase in fatigue life of carbonitrided bearings compared to through hardened bearings.

The bearings had been charged with hydrogen prior to the testing.

“It is supposed that compressive residual stress and larger amounts of retained austenite near the surface, which were formed by the carbonitriding heat treatment were effective against white structure flaking.”

Quote from Uyama and Yamada Paper.

Effect of Heat Treatment on White Structure Fatigue Life
(Source: Uyama and Yamada, NSK Limited)

- Researchers at NSK published figure above showing large increase in fatigue life of carbonitrided bearings compared to through hardened bearings.
- The bearings had been charged with hydrogen prior to the testing.
Resource for More Information

- The paper documenting case study available for download on gearboxfailure.com
- Site also has extensive gearbox reliability and failure analysis resources
Thank you for your attention!

Please submit your questions