EXPERIMENTAL INVESTIGATION OF WIND TURBINE BEARING SUBSURFACE INITIATED DAMAGE

The University Of Sheffield.

PhD student:
Hamza Al-Tameemi: hahal-tameemi1@Sheffield.ac.uk

Project Supervisor:
Dr Hui Long: h.long@sheffield.ac.uk

Wind turbine bearing damage

Wind energy has attracted significant amount of investment during the last decades. However, the complexity of wind turbine design and operation cause an exorbitant cost of maintenance. The bearings of wind turbine gearbox are one of the most vulnerable parts to premature failures.

- Unsteady winds, grid faults, **operational events** →transient dynamic loading, torque reversal , impact load;
- Machine elements operating under different speed and load but the same lubricant is used;
- Misalignment and harsh operational environment;

- Different levels of contact pressure and lubricant film thickness
- Subsurface initiated damage on the non-metallic inclusions
- **Premature bearing failure:** one of the main bearing failures which occurs well below the L_{10} bearing fatigue life is the White Structure Flaking (WSF) and the White Etching Cracks (WECs)

Premature bearing failures

One of the main bearing failures which occurs well below the L_{10} bearing fatigue life is the white structure flaking (WSF).

❖Subsurface initiated WSF at up to 1 mm depth

The subsurface White Etching Areas (WEAs), changes in steel microstructures, are starting points for WECs, which propagate to the surface causing WSF [1,2].

Probable root causes are:

non-metallic inclusions [1,3];

the amount of retained austenite [4];

the level of subsurface shear stress caused by high traction [1];

and the level of Hertzian stress [4].

❖Surface initiated WSF

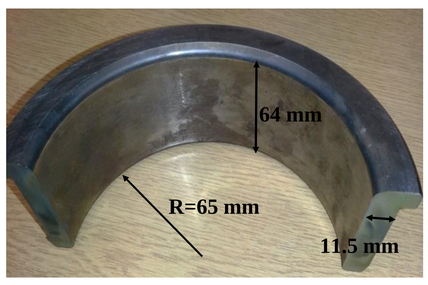
Chemical factors such as oxygen, aging components of the lubricants and hydrogen, combined with loading and environmental factors [2], have a major role in the propagation of cracks. However, there must be a defect on the surface to connect the crack with the propagation factors [2].

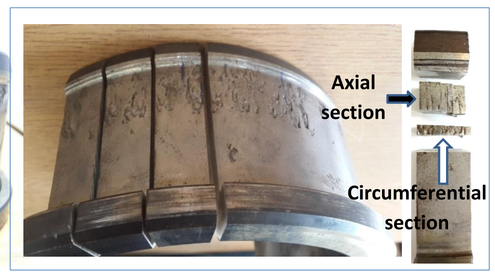
Probable root causes are:

surface flaws; impact/ transient loading or vibration led conditions; and high slippage [3].

Destructive investigation of failed bearing

To develop a better understanding of the deterioration of wind turbine bearings during service an examination of a failed bearing is performed. This bearing was used in a planetary stage of wind turbine. It was in service for five years before failure.





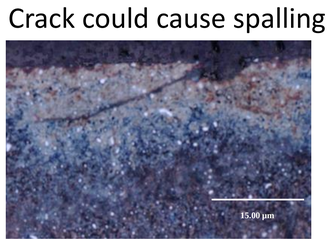
Surface and subsurface features and microstructural damage

Crack could cause micro pitting

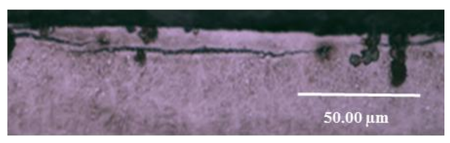
Inclusions of different inclination

WEC propagating to the surface

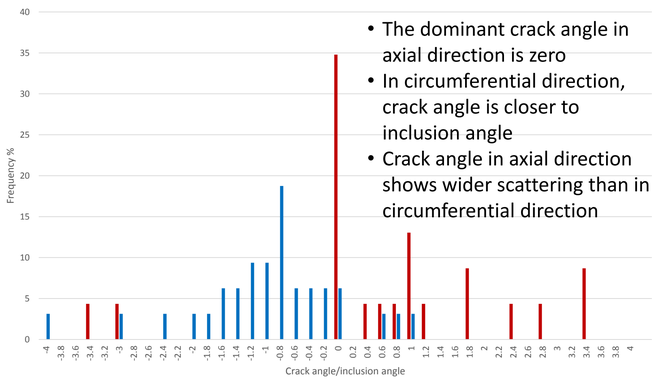
Crack could cause spalling



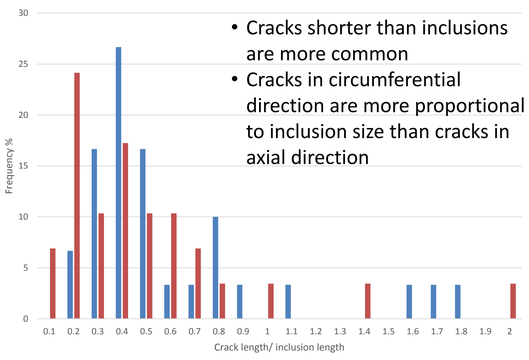
Crack not linked to the surface



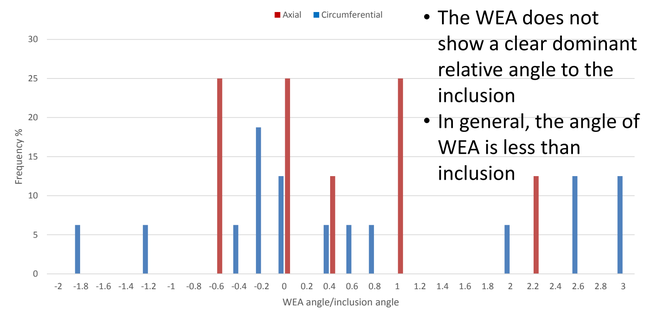
Butterfly wings or White Etching Area (WEA) and micro cracks



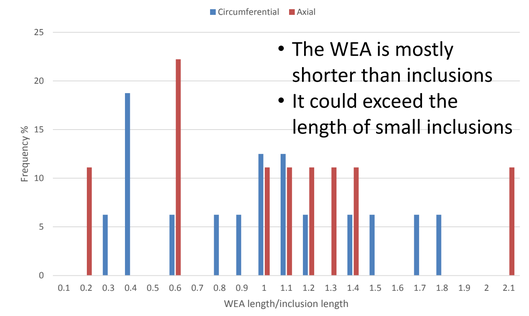
- The dominant crack angle in axial direction is zero
- In circumferential direction, crack angle is closer to inclusion angle
- Crack angle in axial direction shows wider scattering than in circumferential direction



- Cracks shorter than inclusions are more common
- Cracks in circumferential direction are more proportional to inclusion size than cracks in axial direction



- The WEA does not show a clear dominant relative angle to the inclusion
- In general, the angle of WEA is less than inclusion



- The WEA is mostly shorter than inclusions
- It could exceed the length of small inclusions

Different subsurface forms have been observed such as:

- Inclusions with separation only
- Inclusions with WEA only
- Inclusions with Separation and WEA
- Inclusions with Separation, WEA and micro crack

The depth of different damages could be ranked as:

1. Separation from more than 1000 µm to very close to the surface
2. Micro cracks from about 600 to 50 µm
3. WEA from about 400 to 50 µm

References

[1] M.-H. Evans, "White structure flaking (WSF) in wind turbine gearbox bearings: effects of 'butterflies' and white etching cracks (WECs)," *Mater. Sci. Technol.*, vol. 28, no. 1, pp. 3–22, Jan. 2012.

[2] K. Stadler, A. Stubenrauch, "Premature bearing failures in industrial gearboxes ", S. K. F. Gmbh, 2013.

[3] R. J. K. Wood, J. Basumatary, and M.-H. Evans, "Energy-Related Tribo-Corrosion Research at the National Centre for Advanced Tribology at Southampton," STP 1563 *Tribo-Corrosion: Research, Testing, and Applications*, pp. 169–202, 2013.

[4] R. Errichello, R. Budny, and R Eckert3 "Investigations of Bearing Failures Associated with White Etching Areas (WEAs) in Wind Turbine Gearboxes," *Tribology Transactions* 56: 1069-1076, 2013