METALLOGRAPHIC AND TOMOGRAPHIC EXAMINATION OF WHITE-ETCHING CRACKS

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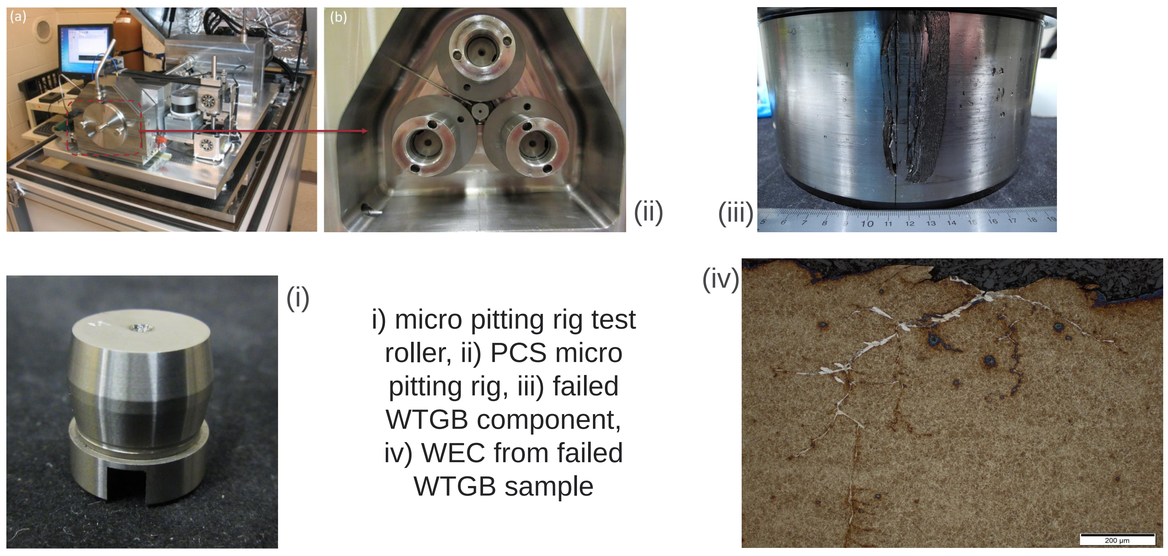
Introduction

- **White-etching cracks** (WEC) form the basis of white-structure flaking, a failure mode common in **wind turbine gearbox bearings** (WTGB). The exact mechanism of WEC formation is unclear, and research is ongoing into why and how these defects form.
- WEC can lead to bearing failure at as low as **~10% of design life.**
- The current project focuses on the identification and study of WEC both in bearings and in controlled laboratory environments. Samples from failed bearings and from **tribometer tests** were subjected to **serial sectioning** and, in the case of the failed bearings, **X-ray microtomography**.



i) micro pitting rig test roller, ii) PCS micro pitting rig, iii) failed WTGB component, iv) WEC from failed WTGB sample

Methods

- Samples from failed bearings were sectioned and examined for the presence of WEC.
- WEC were created in controlled samples in a **three-ring-on-roller micro-pitting rig** (manufactured by PCS instruments)
- Both classes of sample were subjected to serial sectioning and microphotography at roughly 10 µm intervals
- Samples from failed bearings were analyzed using high-power X-ray microtomography at the Advanced Photon Source.

Tomography

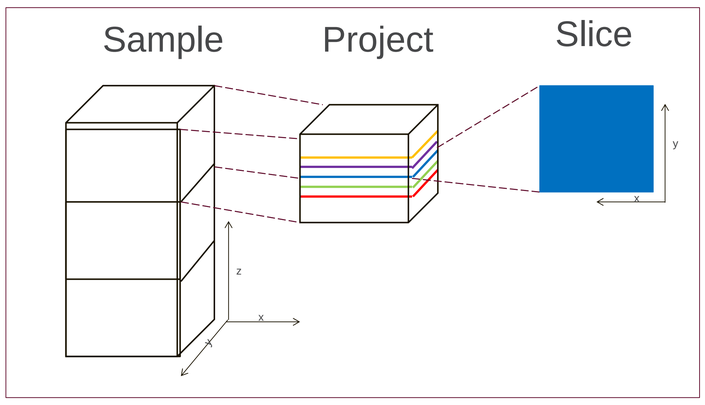
Use Advanced Photon Source beamline 2-BM-A for microtomography imaging

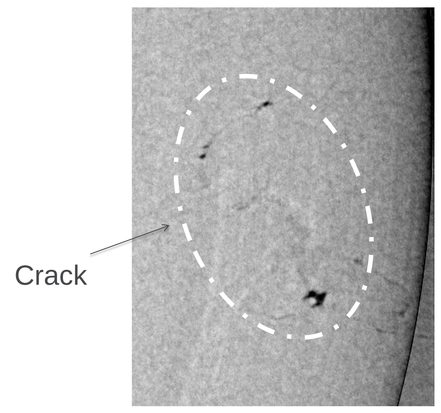
Sample is 2mm x 2mm x 5mm

Use script to slice tomography capture

0.65µm between each slice: 2,040 slices

Use ImageJ software to search for cracks





Serial Sectioning

- Samples are mounted in standard resin pucks
- Samples were polished in successive steps on
  - Three grit sizes (9µm, 3µm, 1µm) of diamond slurry for bulk removal
  - Two grit sizes (3µm, 1 µm) of diamond slurry for serial sectioning
- Rockwell indents were used for determining the location of each section

Method Comparison

Serial Sectioning

- Allows for **viewing of metal microstructure**
- Destructive; physically removes material

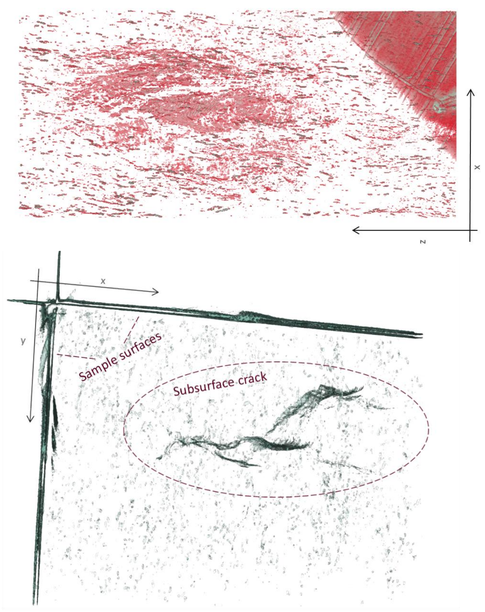
X-ray Microtomography

- **Non-destructive**
- Allows for viewing of **3D structure** of sample
- **Cannot differentiate microstructure**

Methods are complementary; serial sectioning allows for verification of possible WEC found with X-ray microtomography

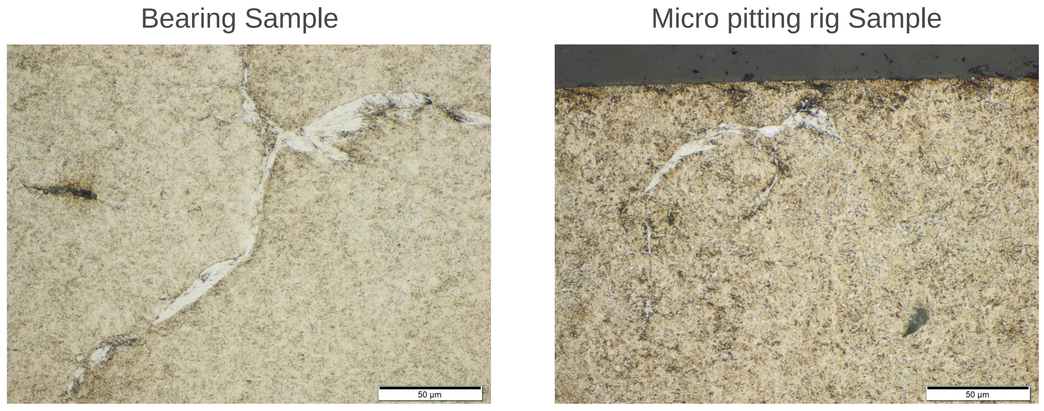
Results

- X-ray microtomography has **successfully been applied to subsurface cracks in bearings** for the first time.
- X-ray microtomography confirms **absence of crack interaction with the surface.**
- Serial sectioning allows for the **verification of the altered microstructure of candidate cracks** from X-ray microtomography.
- Micro pitting rig roller samples produce white-etching cracks **similar to those in failed WTGB**, allowing for experimental determination of the factors leading to WEC formation.



(a)

a) 3D reconstruction crack images from X-ray microtomography, b) WEC found in wind turbine bearing sample, c) WEC found in micro-pitting rig roller sample



(b) (c)

Evans, M. (2016). An updated review: White etching cracks (WECs) and axial cracks in wind turbine gearbox bearings. Mat. Sci. and Tech., 1-37. doi:10.1080/02670836.2015.1133022; Evans, M., Wang, L., Jones, H., & Wood, R. (2013). White etching crack (WEC) investigation by serial sectioning, focused ion beam and 3-D crack modelling. Tribology International, 65, 146-160. doi:10.1016/j.triboint.2013.03.022; Gould, B., & Greco, A. (2016). Investigating the Process of White Etching Crack Initiation in Bearing Steel. Tribol. Lett., 62(2). doi:10.1007/s11249-016-0673-z

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