High-resolution synchrotron XRD analysis for damage-tolerant bearing steel

Bearing is a widely used component that involves moving as rolling parts, especially in vehicles and wind turbines. Even a minor weight reduction in the bearing would significantly reduce fuel consumption and CO_2 emissions. The design of novel steel that allows the manufacture of more compact and lighter bearings would require a better understanding of steel microstructure exposed to cyclic loads. Scatterin AB and Ovako AB teamed up to investigate the microstructure of steel with PETRA III's brilliant synchrotron light.

CHALLENGE

Bearings get exposed to cyclic loads due to rolling contacts while they operate. This exposition causes deterioration within the steel microstructure. The detectable microstructural damages involve stress-induced martensite transformation, the formation of elongated ferrite and ferrite microbands, and the formation of white etching bands and lenticular cementite. Such microstructural changes lead to a lower hardness within the steel subsurface.
The deterioration of the steel microstructure due to cyclic loading also includes cementite dissolution and re-precipitation, and such a phenomenon is strongly dependent on dislocation rearrangement. This makes dislocation density a critical parameter in affecting the microstructural evolution, and accordingly, the performance of a bearing.

However, the investigation of dislocation density evolution in the steel subsurface is so far limited to lab-scale X-ray diffraction (XRD), which was unable to capture the local changes in the subsurface due to the large beam size. Furthermore, due to the low penetration depth, only the near-surface information could be obtained. This hinders the complete understanding of microstructural evolution that can pave the way for designing better steel microstructures for more compact and lighter bearings.

Within this project, SME Scatterin AB teamed up with global engineering steel producer Ovako AB for the 2D mapping of dislocation density evolution in the bearing steel subsurface, using synchrotron X-ray diffraction.

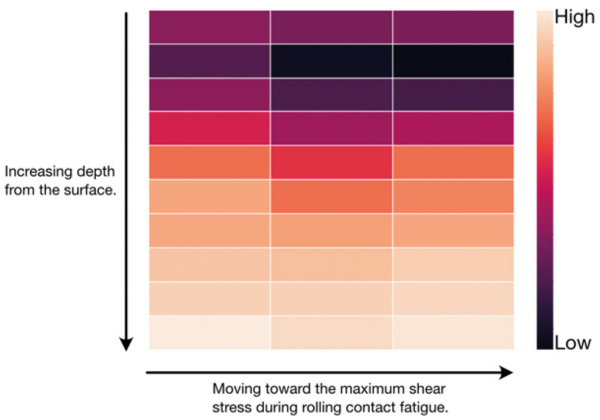

Figure 1: Dislocation density evolution in bearing steel subsurface revealed in μm resolution.

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DESY.

METHOD

Synchrotron X-ray diffraction measurements were performed at the P21.2 Swedish Materials Science Beamline at Petra III, DESY, Hamburg. Using a high-resolution monochromator together with large area detectors and a micro-sized beam enabled to probe and map subtle changes in the steel subsurface, in terms of dislocation density and phase evolution.

ANALYSIS

High-resolution synchrotron XRD has provided essential insights into the evolution of microstructural features that influence the performance of bearing components. These include the quantification of subtle changes in dislocation density and phase fractions. In Figure 1, the dislocation density evolution is sketched depending on the distance from the sample surface and the shear stress value.
Whilst Ovako AB has contributed to the project by providing steel expertise, sample preparation, and complementary lab-scale investigations, Scatterin AB has been responsible for the synchrotron XRD measurements and data analysis using their dislocation density analysis code package as part of their proprietary software: Scatterin SaaS.

BENEFITS

Synchrotron XRD has enabled us to reach an unprecedented spatial resolution in measurements within a significantly shorter duration. High-resolution monochromator, small beam size, and use of large area detectors revealed features and trends that are difficult to observe in the lab instruments. A significant number of measurements were performed within minutes, which would otherwise take days in a lab measurement.

"Synchrotron XRD gave important microstructural information that will assist our development efforts in sustainable and more damage-tolerant bearing steel. We are very happy with the results from our collaboration with Scatterin and DESY." **Steve Ooi, Group Technical Specialist – Ovako**

"We have received excellent support from beamline scientists and the industrialization office. The Swedish Materials Science beamline enables high-quality data to be produced from our experiment. We hope to continue this collaboration in the future." **Ahmet Bahadir Yildiz, CEO – Scatterin**

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