INDUSTRIAL DEVLOPMENT PROJECTS

In-situ X-ray microdiffraction for investigating micro mechanical properties of nitrided steel surfaces along with preparatory X-ray scattering tomography for future in-situ wear testing possibilities

THE INDUSTRIAL CHALLENGE

Heat-treatment using nitriding is common process for Volvo Trucks and Bodycote, which gives the component improved fatigue, wear, friction and corrosion properties. The resulting complex microstructure consists of an outermost compound layer, a few microns wide, followed by a diffusion layer, that can be up to 1 mm deep. As an option, post oxidation can be done to improve corrosion properties. The functional aspects of nitrided layers have been extensively investigated but the knowledge of the micro mechanical and tribological properties requires further insights. The performance is dependent on the chemical composition, crystalline structure, defects/porosity and residual stress state. A methodology is still lacking to evaluate the micro mechanical and wear response of the nitride surface structure non-destructively for optimal performance.

WHY USING A LARGE SCALE FACILITY

The necessity of using advanced characterization techniques to study micro mechanics is obvious and addressed in this work using nanofocused X-ray diffraction (nXRD), with its unique ability for time resolved analysis of the discrete mechanics of oxide layer adhesion that are invisible to lab-based systems that lose signal due to averaging. Additionally, nXRD may isolate localized strain gradients and phase distributions around indentations.

Grazing Incidence X-ray Scattering Tomography (GIXS-CT) leverages high-energy X-rays and overcomes the fundamental limitations of laboratory-based SEM-EBSD or XRD. The high photon energy allows depth-resolved probing in the near-surface region with minimal geometric distortion, providing non-destructive phase distribution across large surface areas. This combination is essential for future in-situ wear testing, providing the high temporal and spatial insights beyond the laboratory techniques capacity.

HOW THE WORK WAS DONE

Nano focused X-ray diffraction was done at NanoMAX beamline MAX IV and supported by beamline scientist Sebastian Kalbfleisch, using a nano-indenter setup provided by Chalmers. Samples with various nitriding were measured, including post-oxidised layer. The measurement position was thinned down to 50 µm to match the X-ray focus depth. The GIXS-CT was carried out at the P21.2 beamline of PETRA III, testing both worn nitrocarburised pin-on-disc tested samples of two steel grades and two different worn gear flanks from Volvo.

THE RESULTS AND EXPECTED IMPACT

The in-situ nXRD retrieved detailed strains and phase distribution of the nitrided layers around the indenter upon increasing loads. The GIXS-CT successfully mapped phase redistribution induced by wear, proving the feasibility of in-situ GIXS-tribology studies. These results provide immediate impact by offering structural feedback to current thermal treatment processes and enhance industrial durability. Future higher resolution GIXS will further refine these models, the current data already provides a critical foundation for decoding and controlling the

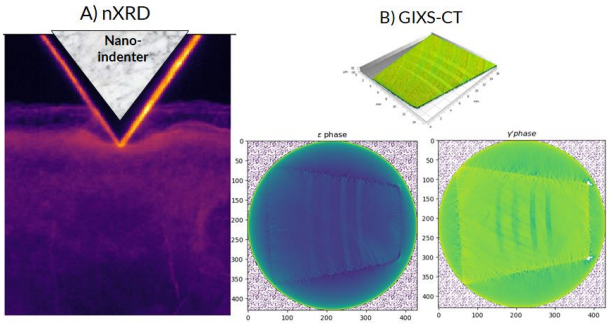

Figure. A) Strain field analysis after nano-indentation, B) GIXS-CT ε and γ' phase distribution of a worn nitrided surface.

"Advanced nXRD Redefines Nitriding Characteristics to Improve Performance in Tough Demanding Applications for Our Customers Components" /Arvin Ghorbani, Bodycote

Inspiring to be a part of this project, performing advance investigation of one of our common heat treatment process" /Lena Magnusson Åberg, Volvo

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