PREPARATORY INDUSTRIAL PROJECT

Suggesting synchrotron techniques for quantitative characterization of nitrocarburized powertrain components

THE INDUSTRIAL CHALLENGE

Every year, more than one million engine gears are produced at Volvo Trucks using nitrocarburizing heat treatment. This surface heat-treatment provides fatigue strength, corrosion protection and low distortion. However, the resulting microstructure is rather complex, consisting of a compound layer (0-0.05 mm) followed by a diffusion zone (0.05-0.80 mm). Accordingly, it is difficult to characterize and thus challenging to tailor its properties for a given application.

To develop better process control methods, which are predictive and accounts for alloying content, a detailed understand is required on how steel grade and processing alters the surface microstructure. That is, in terms of chemical composition, crystalline structure, defects/porosity and residual-stress state.

WHY USING A LARGE SCALE FACILITY?

Synchrotron technique is unprecedented for time-resolved quantitative microstructure characterization. It allows for in-situ and in-operando experimental set-ups to study a materials response on thermal, chemical and mechanical loads. Whereas, lab-based techniques, such as SEM-EBSD, are more limited. That is, limited to 2D surface characterization and low tolerance for larger deformations and lattice defects. In terms of brilliance, a synchrotron source provides ten orders of magnitude more XRD intensity when compared to lab-based techniques. Hence, an experiment that cannot be done or would take weeks in a lab is completed in merely seconds.

THE RESULTS AND EXPECTED IMPACT

Volvo Trucks and RISE have identified 2D- and 3D-XRD mapping as the most promising synchrotron technique to study nitrocarburized powertrain components. It uses a nano- or micron-scale focused X-ray beam to scan over an area in a matrix-like pattern. Each element in the scanning matrix is a 2D diffraction pattern from which the phase structure, lattice constant, and strain distribution can be obtained separately and further reconstructed, analyzed and visualized. Moreover, 2D-XRD mapping can be readily coupled with indentation measurement, for instance at the NanoMAX beamline at MAX IV and at the Nano-focus Xray scattering beamline of the P03 beamline of Petra III in Hamburg. By combining indentation with diffraction mapping, the response of the nitrocarburized surface on a mechanical load can be characterized.

The expected impact by utilizing synchrotron technique is to gain knowledge on how powertrain components are affected and respond on external loads. A first step is to pursue a proof-of-concept by attempting 2D-XRD mapping in combination with nanoindentation.

Figure: Nitrocarburized engine gears

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