INDUSTRIAL PILOT PROJECT

Micromechanical response of nitrocarburized steel studied by in-situ X-ray microdiffraction during nanoindentation

THE INDUSTRIAL CHALLENGE

Steel nitrocarburizing is a surface treatment process that increases fatigue, wear, friction and corrosion properties. The process produces a complex surface compound layer, which consists of two iron nitrides ε and γ'. Moreover, it can be combined with post oxidation to yield a few microns of oxide to further improve corrosion properties. However, a challenge is to understand the micromechanics of this microstructure and thereby tailor the process for performance.

WHY USING A LARGE SCALE FACILITY

X-ray diffraction (XRD) is a direct probe to study the local crystalline deformation and explore micromechanics. At synchrotron radiation sources, the high flux and available micro/nanofocus X-ray beamsize make the scanning diffraction technique feasible tool to map multiscale structures of metal from um to Ångstrom in minutes to hours. This is unlikely to be accomplished by any inhouse X-ray source.

HOW THE WORK WAS DONE

The micro-/nanofocused X-ray diffraction was performed at the P03 'MiNaXs' beamline at PETRA III in Hamburg where a nanoindentation setup is available at the Nanofocus end-station operated by Helmholtz-Zentrum Hereon. By using beamsize around 1 µm, it is possible to map the indentation deformed region at the step of the beamsize. Samples were cut from nitride steel bars and subsequently milled with sinker electrical discharge machining and finally polished by focused ion beam. This made a final thickness of approx. 50 um, with parallel surfaces for incident and exiting beam.

THE RESULTS AND EXPECTED IMPACT

Via microfocused X-ray diffraction, a set of peaks intensity allows to identify crystalline phases and map its spatial distribution. After each indentation step, the shift of the XRD peak position could be used to analyze strain distribution with regards to scanning position, indentation load and diffraction orientation. In the figure an SEM micrograph of a FIB-milled section has been overlayed by this strain field analysis, together with a schematic of the indentation tip. This spatial resolved data unravels the micromechanical response of compound layer during loading.

In total three different steel grades were heat treated by two different nitriding recipes. By characterizing the compound layers formed and their micromechanical response we aim at establishing more detailed requirements on microstructure for optimum performance. In addition, the project developed a data-pipeline for onsite data processing and visualization, which enable prompt data evaluation and rapid experiment improvement.

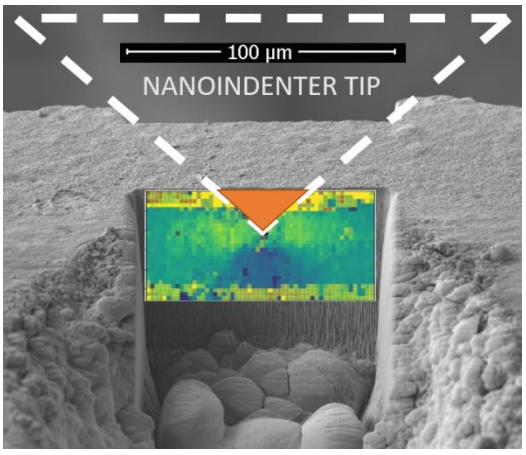

Figure. Strain field analysis overlayed on a SEM micrograph of the FIB-milled section.

"We see an opportunity for tailor-made nitrocarburizing to replace hard chrome in tough applications" /Erik Spolander, Bodycote

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