INDUSTRIAL PILOT PROJECT

Spatially resolved nano-Xray diffraction of advanced metals: machining induced white layers of Ti- and Ni-based alloys

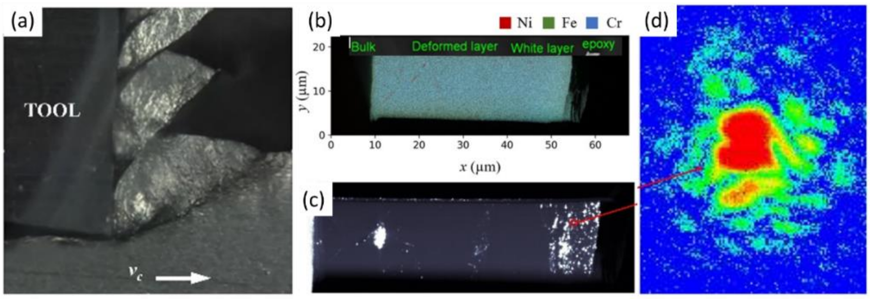

Figure. 1: (a) Photo of the machining process showing the tool and evidencing the formation of the white layer (WL) in machined Inconel 718. (b) High resolution X-ray fluorescence (XRF) map showing the distribution of Ni, Fe and Cr along the lamella. (c) Diffraction map of the lamellae. Bright spots indicate nanocrystalline grains aligned in Bragg condition. (d) High resolution Bragg spot from a selected grain in the WL, evidencing fringes related to its shape and internal strain.

THE INDUSTRIAL CHALLENGE

Recent development of Near net shape manufacturing technologies (e.g. additive manufacturing) offers promising alternatives to conventional processes for the manufacture of titanium and nickel based alloy components. Under conditions of high-speed finishing, the cutting tool is subjected to high temperatures leading to excessive wear thus increasing the risk of causing the subsurface damage called white layer (WL). The formation and properties of WLs are still not fully understood.

WHY USING A LARGE SCALE FACILITY

Studying deformation mechanisms at nano scale and the formation of WL is providing extremely valuable information for the science community and metal industry. Characterization using scanning nano-focused X-ray diffraction (nano-XRD) is necessary to determine, elastic strain, residual stress and phase in the WL and surrounding material. Nano-XRD permits this by allowing a, for example, greater field of view than transmission electron microscope (TEM). Synchrotrons also allow for simultaneous / complementary chemical analyses with X-ray fluorescence, (XRF). Most importantly, however, Bragg Coherent Diffraction Imaging (BCDI) measurements can be performed to investigate the internal strain of individual grains in the WL, something no other technique can do.

HOW THE WORK WAS DONE

High-speed cutting experiments on Inconel 718 specimens were conducted at Seco Tools R&D facility in Fagersta, Sweden. Lamella samples with approximate thicknesses of 1 µm, containing both WL and bulk structure, were prepared using focused ion beam at Lund University. The synchrotron diffraction experiments were conducted at both the P10 beamline (Petra III – Hamburg) and the NanoMAX beamline (MAX IV – Lund). Both beamlines have similar capabilities with the latter offering a much better resolution for nano-XRD and XRF analysis. The thin lamella was studied in transmission geometry and the strain distribution was investigated by tracking the (111) Bragg reflection of the γ phase while the beam was scanned with the sample. Rocking curves were performed on selected grains in the WL, allowing for coherent imaging via phase retrieval algorithms.

THE RESULTS AND EXPECTED IMPACT

The nano-XRD results seen in Figure 1 b-d are providing us with a better understanding of some characteristic features of the WL for example by revealing an, until now, unidentified strain structure in the top surface white layer. The analysis of individual grains of the WL with BCDI suggests it is possible to use this method for the reconstruction of individual grains and map their internal strain field. Replicating such measurement across multiple grains would allow us in the future to obtain relevant information about fine structured strain gradients inside typical WL grains, and grain statistic across the WL phase. Such detailed strain fields are currently not achievable with a lab-based TEM.

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