INDUSTRIAL PILOT PROJECT

Stress mapping on ultra-high strength steel (UHSS) cut edges using high-energy X-ray diffraction

THE INDUSTRIAL CHALLENGE

During cutting operations in the process route from steel plate to finished product stresses can be introduced that can be detrimental later in the products life. This is especially true in connection with fracture induced by hydrogen embrittlement (HE). A prerequisite for HE is the introduction of residual stresses originating from plastic deformation during the cutting process.

WHY USING A LARGE SCALE FACILITY

The investigation and optimization of the internal stresses introduced during the cutting process is clearly important. Direct measurements of residual stresses on the microscale would open new ways for optimizing materials and cutting processes for high strength steels. The best conventional XRD has probes with a diameter of 0.5 mm and a depth penetration in steel of 20 µm. This makes local measurements with the required geometry impossible. With the deep penetration and a small probe of high energy X-ray sources; however, such measurements become possible.

HOW THE WORK WAS DONE

We used pencil-beam high-energy X-ray diffraction at the Swedish beamline P21.2 of the synchrotron PETRA III, Hamburg, to map stresses down to the microscale at cut edges. The work was done by representatives from SSAB Europe with support by expertise from Swerim and DESY. The UHSS material analysed was a commercial steel Docol™ 1200M from SSAB Borlänge, with approximately 1 mm thickness. This is mainly intended for use in the automotive industry and is fully martensitic with a minimum tensile strength of 1200 MPa. The material was cut using three different methods; shearing, shearing followed by milling, and by using a CO_2 laser. The cross-sections could be inspected perpendicular to the cut edge in transmission mode. For mapping of the residual stresses, a 30 µm beam was scanned over the sample and a diffraction pattern was collected every 50 µm. Residual macro stresses (or type I) were evaluated by examining the peak shift at the north and east direction of the detected Debye rings.

THE RESULTS AND EXPECTED IMPACT

The residual stresses could be studied with impressive resolution.

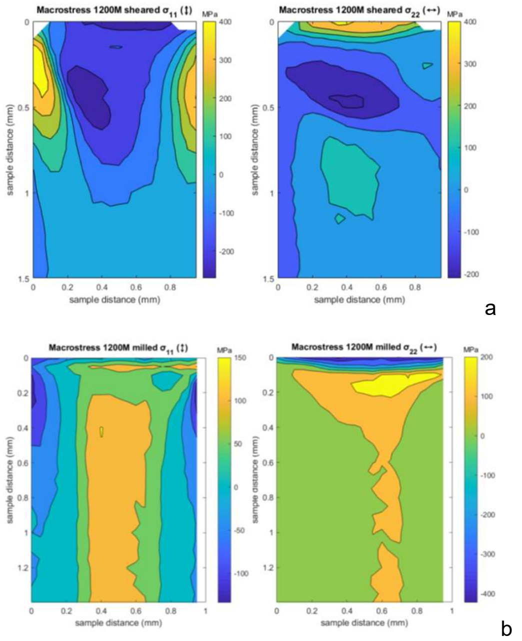

Figure. The constructed macro strain maps calculated by the determined cell parameters in the north (σ11) and east (σ22) direction for the a) sheared sample and b) sheared and milled sample.

The dangerous localized tensile stresses were only found in the sheared samples. These stresses could serve as driving force for crack propagation during HE. Subsequent milling was found to introduce compressive stresses in the immediate surface and therefore reduce the sensitivity for HE.

"This unique XRD method can explain why certain cutting methods should be avoided for processing of UHSS in order to reduce high local tensile stresses and improve HE resistance. It will be a valuable tool for modifications of materials and cutting processes."
/Sven Erik Hörnström, senior expert at SSAB

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