INDUSTRIAL PILOT PROJECTS

Improved steel cleanliness analysis with inclusion detection and quantification using synchrotron X-ray microtomography

THE INDUSTRIAL CHALLENGE

Foreign particles (inclusions) in steel, originating from early stages in the steel production process may reduce mechanical properties. As a world leading steel producer SSAB constantly strives to improve the cleanliness of the steel and one key is improved methods for the detection and quantification of inclusions.

WHY USING A LARGE SCALE FACILITY

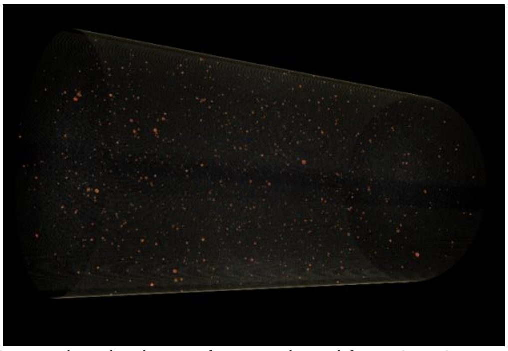
Present standard techniques to investigate steel cleanliness are 2-dimensional (2D), e.g. light optical microscopy (LOM) and scanning electron microscopy (SEM). These methods are limited since interpretation by stereographic methods and assumption of a regular inclusion size distribution must be done in order to obtain size, shape and volume fraction of the inclusions. Difficulties arise when inclusions are few or when there is a varying orientation or shape of inclusion particles and irregularities in the inter-particle connectivity. The 3D nature of non-destructive tomographic imaging techniques can overcome this. The low X-ray intensity of laboratory-based X-ray tomography (µCT) demands for a longer scan time, thus making impeding the technique to be used on a commercial basis. With the high beam brilliance at a modern synchrotron source, X-ray microtomography SRµCT is less time consuming. Following the recent developments and increased availability of SRµCT combined with optimized work-flows for image analysis, this technique could potentially be offered as a standard and routinely used technique for industrial inclusion assessments.

HOW THE WORK WAS DONE

The inclusion detection and quantification SRµCT experiments were performed at the P07 High Energy Materials Science (HEMS) beamline of Helmholtz-Zentrum Geesthacht at the PETRA III storage ring at the DESY synchrotron in Hamburg, Germany. 12 samples of low carbon steel were prepared as rods with 10 mm height and 1-2 mm in diameter. To validate the results of the SRµCT measurements, standard testing was done using microscopy methods, i.e. LOM and SEM.

THE RESULTS AND EXPECTED IMPACT

With the SRµCT method, it was possible to detect inclusions down to the size of 2.4 µm, which is similar to standard 2D techniques, however with a much shorter scan time, about 15 min compared to several hours for standard 2D techniques. The image below shows a 3D rendering of a sample volume, where the inclusions are clearly visible.



3D rendered volume of a sample rod from SRµCT.

For image analysis of individual inclusions, an automatic image analysis script in Python was developed. The quantitative results of SRµCT, LOM and SEM showed strong mutual correlation. Also, the SRµCT revealed the actual size distribution of the inclusions in the samples. Proven as a fast and precise method for 3D inclusion assessment, a very interesting next step would be to test steels for correlation between SRµCT data and relevant mechanical properties.

SSAB SWERIM RISE Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research DESY.

Contacts: Niklas Kojola - SSAB AB. niklas.kojola@ssab.com
Fredrik Lindberg - Swerim AB, fredrik.lindberg@swerim.se
Emanuel Larsson – RISE Research Institutes of Sweden, emanuel.larsson@ri.se

Vinnova's project No: 2018-04418 **Duration:** November 2018 -- March 2020

Funded by Sweden's Innovation Agency, Vinnova, in order to build competence and capacity regarding industrial utilisation of large-scale research infrastructures such as MAX IV and ESS.