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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 (μ CT) 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 SR μ CT is less time consuming. Following the recent developments and increased availability of SR μ CT 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.

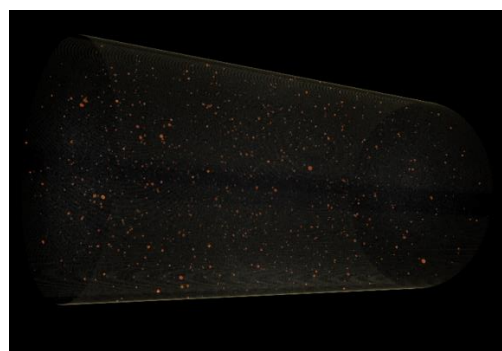
HOW THE WORK WAS DONE

The inclusion detection and quantification SR μ CT 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 SR μ CT measurements, standard testing was done using microscopy methods, i.e. LOM and SEM.

THE RESULTS AND EXPECTED IMPACT

With the SR μ CT method, it was possible to detect inclusions down to the size of 2.4 μ m, 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 SR μ CT.

For image analysis of individual inclusions, an automatic image analysis script in Python was developed. The quantitative results of SR μ CT, LOM and SEM showed strong mutual correlation. Also, the SR μ CT 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 SR μ CT data and relevant mechanical properties.



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