Fast Computed Tomography with Sub Micron Resolution for the Investigation of Microstructures

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Abstract

The microstructural analysis of metal alloys is usually done by – destructively - preparing cuts through the object and subsequent examination with light-optical-microscopy (LOM) or secondary electron microscopy (SEM). The conventional method allows only for 2-dimensional (2D) views of a single surface previously prepared by cutting. Thus, an analysis of a whole 3-dimensional (3D) volume involves the time consuming and possibly inaccurate preparation of multiple cuts and the following fusion to a 3-dimensional data set.

Upcoming new methods like focused ion beam (FIB) tomography in principle allow for a user friendly 3D analysis of microstructure on a very fine scale, but the method is still very time consuming and the investigated volumes are still very small.

Since a few years computed tomography (CT) provides an alternative approach which closes the gap between the 2D methods performed on a large object area and the scans of very small volumes with the resolution on a nanometer scale in 3D.

Recent developments in the field of X-ray imaging, including detector and X-ray production technologies, allow for an increasing spatial resolution on growing volume sizes [larger than (2 mm)³], and at the same time within shorter duration of the measurements. Important developments of submicron CT-technology take place on two main fields today: on the one hand by increasing the output of the X-ray sources and the efficiency of the flat panel detector systems, CT data acquisition has become extremely fast, with resolutions down to a few microns and a total scan time of below 30 s.

On the other hand, the overall improvement of the CT equipment allows for improving spatial resolution far better than 1 micron, thus really opening the realm of nano X-ray imaging.

Nevertheless, for high resolution efforts some physical limits of the non-destructive application are reached like for instance the maximum sample size of just a few millimetres. The result of the CT measurement relies on the quality of each transmission image from a 360° angular range. Thus, for microstructure analysis efforts, where the contrast of single material phases is an issue, the penetration lengths should remain as constant as possible in order to minimize beam hardening artifacts and loss of contrast. Hencefore, a round shape of the sample improves the quality of the representation of its inner structures.
In this contribution we present the capabilities of CT for the 3D analysis of microstructures in aluminium alloys regarding the fast micro-CT as well as highest resolution nano-CT application.

Furthermore, results from a dual-energy CT approach at the nano meter scale will be presented.