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Edge enhancement investigations by means of experiments and simulations

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Abstract

Standard neutron imaging procedures are based on the "shadow" of the transmitted radiation, attenuated by the sample material. Under certain conditions significant deviations from pure transmission can be found in the form of enhancement or depression at the edges of the samples. These effects can limit the quantification process in the related regions. Otherwise, an enhancement and improvement of visibility can be achieved e.g. in defect analysis. In systematic studies we investigated the dependency of these effects on the specific material (mainly for common metals), such as the sample-to-detector distance, the beam collimation, the material thickness and the neutron energy. The beam lines ICON and BOA at PSI and ANTARES at TU München were used for these experiments due to their capability for neutron imaging with highest possible spatial resolution (6.5 to 13.5 micro-meter pixel size, respectively) and their cold beam spectrum. Next to the experimental data we used a McStas tool for the description of refraction and reflection features at edges for comparison. Even if minor contributions by coherent in-line propagation phase contrast are underlined, the major effect can be described by refraction of the neutrons at the sample-void interface. Ways to suppress and to magnify the edge effects can be derived from these findings.

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Keywords: phase contrast, refractive index, edge enhancement, beam collimation, simulation, energy dependency

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1. Introduction: the edge features in neutron imaging

Neutron imaging data are obtained in transmission mode as “shadow” on a two-dimensional neutron sensitive detector where the local attenuation defines the contrast per pixel. In most cases, reverse calculations using the attenuation law can be done in order to derive information about composition, thickness or density of the investigated object in a quantitative way. A typical example of a flat sample is given in Fig. 1 for a dried fish, illustrating the state-of-the-art in neutron imaging with respect to contrast, spatial resolution and field of view. The high sensitivity for hydrogenous materials is the reason for this impressive contrast in the neutron data.

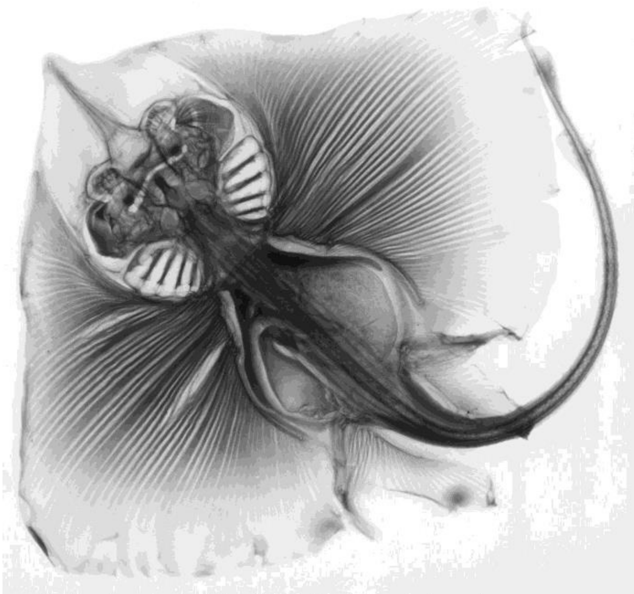

Fig. 1: Neutron transmission image of a dried fish – a ray - (sample size about 15 cm in diameter) showing many details of the organic structure, mainly caused by the attenuation in the hydrogenous material; in this setup, no phase-contrast features are induced and visible. The image was taken at the thermal beam line NEUTRA at SINQ, PSI, using a neutron sensitive imaging plate

However, under certain conditions these transmission images deviate strongly from the pure attenuation behavior. At the edges of the samples we recognize strong local contrast enhancements, as shown in Fig. 2 for the examples of metallic parts (steel, Ti).

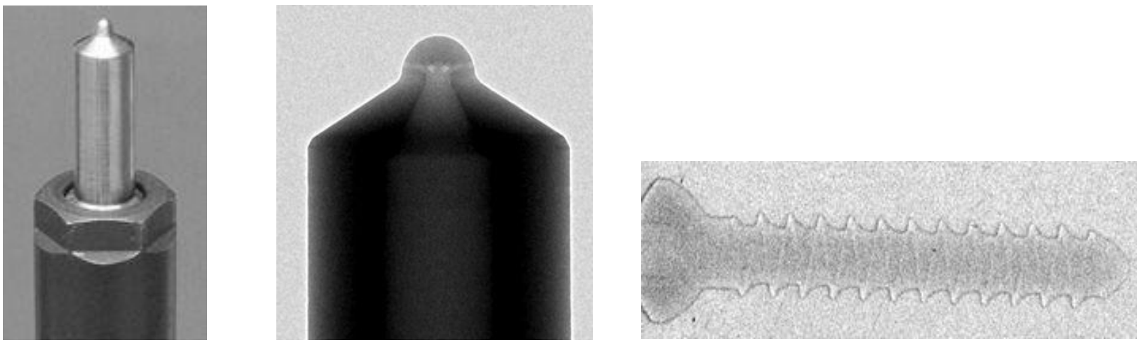

Fig. 2: Objects with edge enhancement features: left, middle: steel injection nozzle; right: Ti screw. The measurements were done at the cold neutron imaging facility ICON with a high resolution detector, sample size on the order of 20 mm, pixel size 0.0135 mm.