1.4.29. A SOFTWARE SIMULATION TOOL DEDICATED TO THE DESIGN AND EVALUATION OF X-RAY BACKSCATTER SYSTEMS

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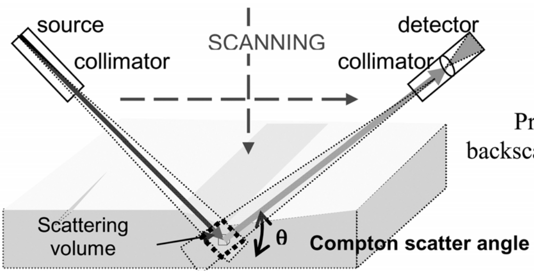
1. Introduction. Backscatter X-ray technique is a suitable technology for the inspection of single-sided access objects. The purpose is the detection of subsurface defects or non-homogeneities, or the measurement of the thickness of sub-surface layers. The principle is based on scattering effect: X-rays are emitted from a collimated source, most of the photons are attenuated by the sample, but part of them are scattered, within any angles, and may be measured by one or several detectors. This scattered radiation depends on the object structure and on the effective atomic number of the materials, thus contains information about the object inside.

By applying a suitable collimation to both source and detector, an elementary inspection volume is defined, at a given focal depth. A scanning is accomplished by moving the system relative to the sample. This technique, often called “flying spot”, requires long time for the inspection of large volume. By using a number of detectors arranged side by side, one can obtain a higher speed. A slightly different technique, “imaging” technique, consists in using a collimation system such as a pin-hole to image directly an intermediate volume on a 2D detector. In fact, backscatter technique has existed for a long time. But the availability of new types of detectors is offering new functionalities and performances. Counting mode detectors, providing the total number of photons, are convenient for sub-surface defect detection. Spectral mode detectors, able to give the actual spectrum of the scattered photons, may perform discrimination between different material layers.

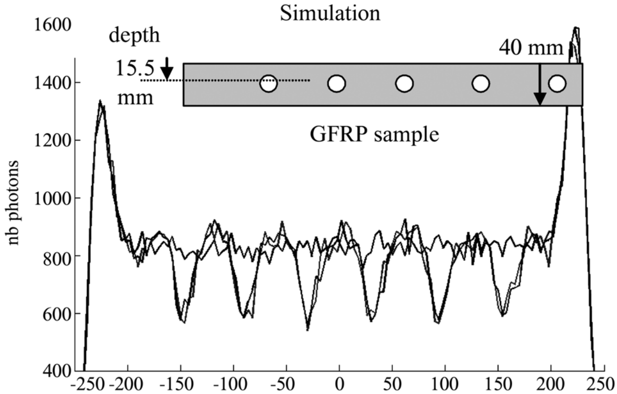


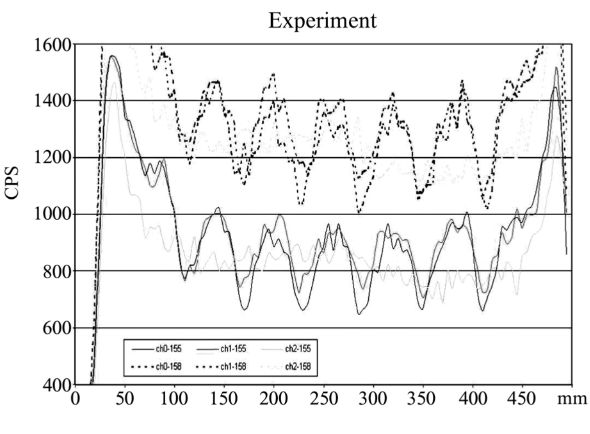
Principle of backscatter technique

A backscatter system presents a lot of parameters: characteristics of the source, collimation of it, characteristics of the detector, collimation, relative angles and geometry, scanning geometry. These parameters have to be optimized depending on the sample (shape and material) and the potential defects. We have developed a simulation software tool to model the signal provided by such a system. This tool allows the multi-parametric optimization of the system. It also helps the interpretation of the data, and the development of specific data processing. This paper presents this modeling tool developed at CEA-LETI, illustrated by examples and comparison with true experiments performed at Innospexion.

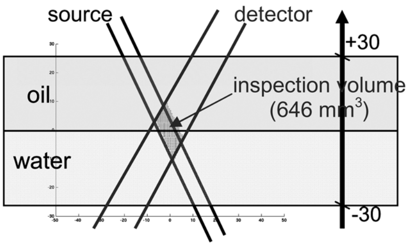
2. Development of a dedicated simulation software. An analytical simulation tool has been developed to predict the scan profile resulting from X-ray backscatter measurements. This tool is able to model any polychromatic source, any detector and any geometric configuration, any sample and any type of defect. The physics involved in the system concerns X-ray / matter interaction, including both attenuation aspects (Beer-Lambert law) and Compton scattering. The code uses a ray-tracing algorithm and can deal with complex objects. Accurate models of collimation allow the efficient calculation of the inspected volume. We assume that most of the scattered photons in backscattering inspection come from first Compton scattering. Single Compton scattering can be modelled analytically (Klein Nishina formulae), allowing fast computation. The contribution of multiple scattering is low, and induces only an additional scatter level, low-frequency signal (spreading phenomena). In cases where multiple scattering can not be neglected, a Monte Carlo simulation is possible but very time consuming. This Monte Carlo code has been used to validate the analytical software. Comparison with true experiments has also been performed.

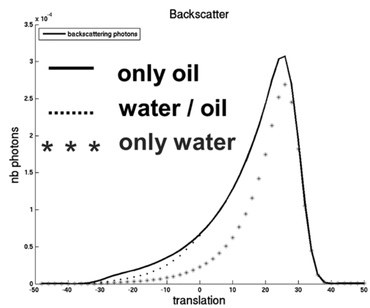
3. Results of backscatter simulation, comparison to experiments. The first example concerns a GRFP sample (40 mm thick) with several defects of 20 mm diameter. The technique applied is “Flying spot” with 50 kV, 0.35 mA. The scan is performed horizontally. Backscatter profiles through defects (red & blue) and outside (black in simulation) are presented.





The second example concerns the study of the interface between two close materials layers (water and oil). The technique is also flying spot, here at 30 kV, but the scan is performed vertically. With a counter mode detector (which is simulated) the interface is slightly visible, the result would be better in spectral mode.





4. Conclusion. We have developed a simulation software which purpose is to help the optimization of a backscatter system depending on the inspection task (sample, defects). Moreover, by easily changing parameters, this tool is very useful to help the interpretation of backscatter profiles, which is clearly not obvious.