Dual axis Dark Field Contrast Tomography for visualisation of scattering directions in a CFRP sample

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Summary: In Carbon Fiber Reinforced Polymer (CFRP), the carbon fibers embedded into the polymer matrix cause scattering when inspected with X-rays. This scattering is captured within the dark field image when the sample is scanned with a grating based Interferometer. The main disadvantage is, however, that only directional scattering information can be achieved due to the orientation of the gratings. By scanning the sample twice, with a 90 degrees rotation of the sample in between, information from two different scattering directions can be combined into one 3D reconstruction volume. In this abstract, such an approach is shown to improve the representation of scattering inside the sample.

Introduction

The success of Carbon Fiber Reinforced Polymer (CFRP) in different industries is due to the distribution of carbon fibers throughout the resin matrix, which provides its strong material qualities. The distribution of the fibers is crucial for the final material strength. To visualize the fiber bundles, CFRP samples can be scanned with phase contrast computed tomography (PCCT) using a grating based interferometer (GBI) through a phase-stepping procedure [1]. This procedure allows to acquire three different images: an absorption image, a refraction image and a dark field image. In this work, we are interested in this dark field image since it visualizes the scattering caused by the fibers throughout the material. With GBI-PCCT, however, it is only possible to visualize the scattering in one direction due to the orientation of the gratings. By rotating the sample around an axis perpendicular to the gratings, scattering information from different directions can be recorded. Based on the obtained dark field images, directional scattering information can then be visualized [2]. In this work, we propose to use a dual axis scan to improve the dark field 3D reconstruction of scanned CFRP samples, along with a combined tomographic reconstruction approach.

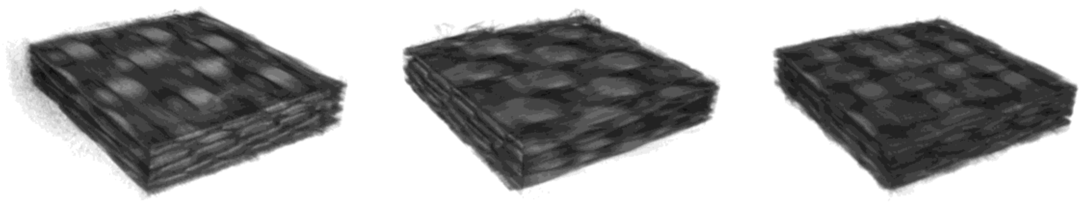
Method

To improve the scattering information in a 3D dark field tomographic reconstruction, a sample was scanned twice in the interferometer with the same scanning parameters but once rotated over an angle of 90 degrees around the axis connecting the source with the detector. This way, scattering information from two perpendicular directions was available. Based on the acquired projection data from both scans, one reconstruction was computed. To make this tomographic reconstruction, three steps were required. In a first step, the holder had to be subtracted from the projection images. The reason for this step is that the holder is still at the same position while scanning the object in the rotated position, causing the position of the holder to be in a different position compared to the sample after reconstruction of the rotated sample. The subtraction was done by thresholding the holder from the reconstructions and then subtracting forward projections of the holder from the original projections. Secondly, a reconstruction of the absorption data of both the scans was made. The two reconstructions were then registered using ASTRA toolbox [3] based alignment software to find the exact orientation of the scans compared to one another.

Once the orientation was found, in a third step, one dual axis reconstruction was made of both datasets.

Experiments and Results

The same CFRP sample was scanned at the University of Applied Sciences in Wels with a GBI. For each orientation of the sample, 1200 projections were taken over a range of 360 degrees. After registration, we found that the second scan was obtained after a rotation of around 87.3 degrees and a slight translation and tilt. Figure 1 shows 3D dark field SIRT reconstructions of the sample at zero degrees and at 90 degrees and a dual axis reconstruction which combines both projection datasets. In Figure 2, a cross-section of the three reconstructions is shown. One can see that each of the two scans visualizes fiber bundles oriented in one direction and does not show the fiber bundles in the orthogonal direction. Combining the two datasets gives a better representation of the complete fiber structure inside the sample.



(a) (b) (c)

Figure 1: 3D SIRT reconstruction of the scattering in the sample scanned at zero degrees rotation (a), at 90 degrees rotation (b) and a dual axis 3D reconstruction (c)

(a) (b) (c)

Figure 2: cross-section of a 3D SIRT reconstruction of the scattering in the sample scanned at zero degrees rotation (a), at 90 degrees rotation (b) and a slice of a dual axis 3D reconstruction (c)

Conclusion

For visualization of the fiber structure inside a CFRP sample, it is beneficial to scan the sample twice, with a 90 degrees rotation in between, and use both sets of projection data to make one 3D reconstruction. This way, fiber bundles with different orientations are visualized in one reconstruction. In this paper, SIRT was used as a reconstruction algorithm. It should however be noted that the forward and backprojection model used in the SIRT algorithm does not give a good description of the scatter physics. Therefore, in the future, we will describe this model more realistic and obtain better suited reconstruction algorithms for scattering images.

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