A workflow to reconstruct grating-based X-ray phase contrast CT images: application to CFRP samples

J. SANCTORUM[1], E. JANSSENS[1], A. J. DEN DEKKER[1,3], S. SENCK[2], C. HEINZL[2], J. DE BEENHOUWER[1], J. SIJBERS[1]

[1]*imec-Vision Lab, University of Antwerp, Belgium, e-mail: jonathan.sanctorum@uantwerpen.be*

[2]*Research Group Computed Tomography, University of Applied Sciences Upper Austria, Austria*

[3]*Delft Center for Systems and Control, Delft University of Technology, The Netherlands*

Summary: Carbon fibre reinforced polymer (CFRP) is an extremely strong and lightweight plastic of which the strength depends on the distribution of its fibres. Fibre bundles can be visualized by means of phase contrast X-ray computed tomography (PCCT) based on grating-based interferometry (GBI). However, many steps are involved in the reconstruction of GBI-PCCT images. In this abstract, a workflow for the reconstruction of 3D CFRP phase contrast images based on GBI projection data is presented.

Abstract: Within recent years, the need for new, cost-effective, function-oriented, highly integrated, and lightweight components has strongly grown. Carbon fibre reinforced polymers (CFRPs) outperform conventional materials such as aluminium, steel or alloys in terms of high strength, elasticity, durability, energy efficiency, and weight [1]. To design optimal components, detailed investigations of CFRP materials are vital. To visualize the fibres and fibre bundles inside the samples, phase contrast X-ray computed tomography (PCCT) can be applied. This technique allows reconstructing 3D images of CFRP samples from projection data, acquired with, for example, a grating based interferometer (GBI) through a phase-stepping procedure [2]. Many processing steps are involved in such a GBI-PCCT reconstruction pipeline, each of which significantly affects the final image quality. The aim of this work is to present a workflow to process GBI-PCCT data and reconstruct 3D images of CFRP samples, and to study the effect of each pre-processing step.

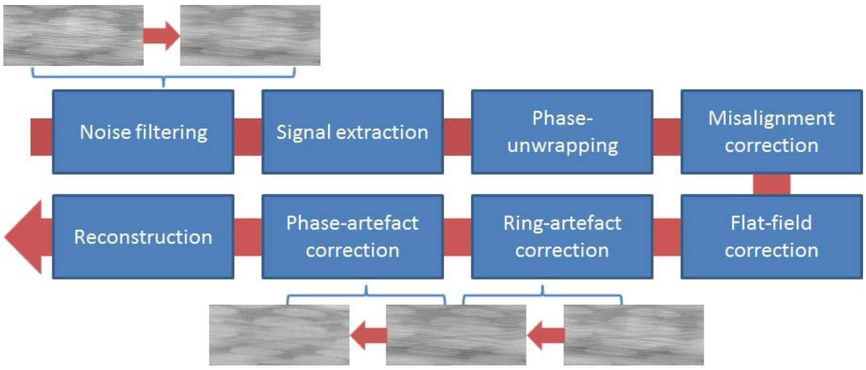

Fig. 1: Schematic overview of the presented reconstruction pipeline. To illustrate the effect of the pre-processing steps, CFRP reconstructions with and without performing certain pre-processing steps are shown.

The first step in the reconstruction pipeline is noise filtering of the raw phase-stepping projection data. We opted for a block-matching noise filter [3] to be applied to the raw projection data, as it performs very well with respect to reducing noise, while preserving fine details. As a consequence, the noise in the projections was suppressed, which resulted in a more robust signal extraction and less noise in the final phase contrast reconstruction. After the noise filtering procedure, the different image modalities, including (differential) phase contrast, were extracted from the projection data [2]. The resulting phase contrast projections contained wrapped phase values, which had to be unwrapped (Fig. 2). While many algorithms have been presented, a recently launched, open source, accelerated phase-unwrapping algorithm was found to be best performing in terms of robustness and speed [4]. After phase-unwrapping, and before applying flat-field correction, the projections were corrected for possible rotation axis misalignment. The final reconstruction quality was further improved by correcting for ring artefacts resulting from deviating detector pixel responses [5]. Furthermore, a correction for incorrect phase values, originating from incorrect phase unwrapping results or differential phase clipping, was attained by using a phase weighting technique [6]. Finally, the 3D PCCT image was reconstructed from the pre-processed projection data using the ASTRA-toolbox [7].

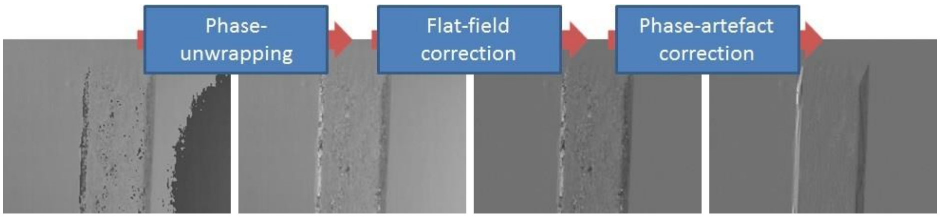

Fig. 2: The effect of different pre-processing steps on the differential phase-contrast projection data.

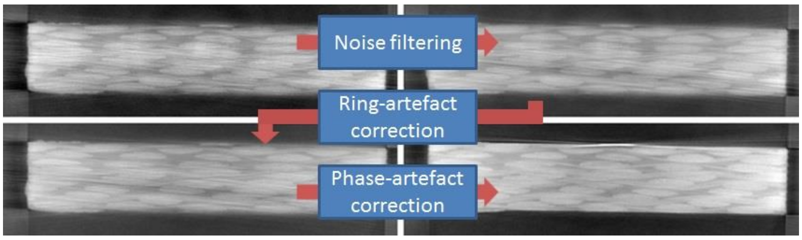

Fig. 3: The effect of different pre-processing steps on the final phase-contrast reconstruction.

As can be seen from Fig. 1 and 3, each pre-processing step significantly contributes to an increase in the quality of the final reconstruction. This demonstrates that the analysis of CFRP samples based on X-ray GBI projection data may greatly benefit from an optimized pre-processing procedure. Therefore, sufficient attention should be given to the pre-processing of the experimental data, before the actual reconstruction and analysis is performed.

In conclusion, in order to optimize the quality of GBI-PCCT images of CFRP samples, adequate pre-processing of the projection data before reconstruction and analysis is paramount.

Acknowledgments

This research is funded by the FFG Bridge Early Stage project no. 851249 (ADAM) as well as the Fund for Scientific Research-Flanders (FWO, grant no. G0F9117N).

References

[1] Chen, Y. et al. (2015) In: *IWMECS 2015*, Paris, 2015. France: Atlantis Press, p. 53-57
[2] Bech, M., et al., *Zeitschrift für Medizinische Physik*, **20(1)**, 7-16, (2010)
[3] Dabov, K., et al., *IEEE Transactions on Image Processing*, **16(8)**, 2080-2095, (2007)
[4] Blinder, D., et al., *Optics Express*, **24(20)**, 23094, (2016)
[5] Sijbers, J., et al., *Physics in Medicine and Biology*, **49(14)**, N247–N253, (2004)
[6] Jerjen, I., et al., *Optics Express*, **19(14)**, 13604, (2011)
[7] van Aarle, W., et al., *Optics Express*, **24(22)**, 25129, (2016)