TALBOT-LAU GRATING INTERFEROMETER XCT FOR POROSITY DETERMINATION IN CFRP WITH METAL COMPONENTS IN COMPARISON TO OTHER NDT INSPECTION METHODS

Christian Gusenbauer*[1], Michael Reiter[1], Bernhard Plank[1], Günther Mayr[1], Stefanie Renner[2],
Elisabeth Leiss-Holzinger[3], Bernhard Reitinger[3], Peter Burgholzer[3], Martin Barth[4], Bernd Köhler[4], Johann Kastner[1]

[1]University of Applied Sciences Upper Austria, Stelzhamerstraße 23, 4600 Wels, Austria
[2]FACC Operations GmbH, Fischerstraße 9, 4910 Ried im Innkreis, Austria
[3]Research Center for Non Destructive Testing GmbH, Altenberger Straße 69, 4040 Linz, Austria
[4]Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Maria-Reiche-Straße 2, 01109 Dresden, Germany

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Summary: In this contribution we present multi-modal image data acquired by using a commercially available Talbot-Lau grating interferometer µXCT desktop device, conventional attenuation-based µXCT devices and other NDT inspection methods. We show that the differential phase contrast (DPC) modality, acquired by the Talbot-Lau system, is less prone to metal streaking artefacts allowing a more reliable inspection of pores close to metal components.

1. INTRODUCTION

The Talbot-Lau grating interferometer µXCT system extends the imaging capabilities of conventional µXCT systems, which are mainly restricted to attenuation contrast (AC), with additional imaging modalities such as differential phase contrast (DPC) and dark-field contrast (DFC). Up to now, DFC turns out to be the key imaging modality for materials science, since it is capable of revealing internal structures and defects such as micro-porosity or cracks in the sub-voxel region, which can be smaller than the spatial resolution of the respective XCT system [1-2]. Even though DPC has proven its usefulness by improved contrast in soft tissue and biological cases, there is a rather low impact on materials science applications.

The investigated carbon fibre reinforced polymer (CFRP) sample consists of stacked fabric layers made of woven carbon fibre bundles, and a copper mesh, embedded in a matrix that is made of different resin types. The copper mesh near the surface is intended for lightning protection and causes strong metal streaking artefacts due to scattered radiation and the polychromatic nature of industrial X-rays, which degrade image quality and hinder proper failure analysis and segmentation. Important material characteristics are the distribution and orientation of the fibre bundles, density variations within the matrix and the number and distribution of pores, which are caused by trapped volatiles in the resin. The scanning task primarily includes the detection and characterization of internal defects such as pores while achieving the best possible image quality.

2. EXPERIMENTAL METHOD

For this study a commercially available Talbot-Lau grating interferometer µXCT desktop system (SkyScan 1294) using a phase stepping approach has been utilized to characterize the CFRP sample with AC, DPC and DFC imaging modalities. Each imaging modality offers specific insights into the material system, since the Talbot-Lau grating interferometer method is sensitive to different material properties. The interaction mechanisms of X-rays with matter (such as attenuation, refraction and scattering) can be extracted separately with one single measurement.

Furthermore, the Talbot-Lau results will be compared to metal artefact reduction (MAR) methods applied to AC data, which are based primarily on sinogram inpainting [3], as well as to other NDT inspection methods such as

* e-mail: christian.gusenbauer@fh-wels.at

e.g. optical coherence tomography (OCT), scanning acoustic microscopy (SAM), laser ultrasonics (LUS) and active thermography (IR).

3. RESULTS

The results concerning multi-modal characterization with a Talbot-Lau system suggest the applicability of DPC to multi-material systems such as CFRP with a copper mesh (see Figure 1b), further expanding the possibilities of Talbot-Lau imaging for materials science applications. DPC provides less metal streaking artefacts, better contrast and less noise, thus greatly improving the detection of pores in CFRP located close to metal components. In addition, DFC can be used to visualize individual fibre bundles and emphasize different orientations. Since the DPC modality offers a nearly artefact free inspection of pores located close to the copper mesh, DPC is used to extract quantitative material values such as porosity for different region of interests (see Figure 1d).

The benefits and limitations of Talbot-Lau imaging will be discussed in comparison to other NDT inspection methods regarding image quality, scanning effort and throughput rates.

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References

[1] V. Revol, I. Jerjen, C. Kottler, P. Schütz, R. Kaufmann, T. Lüthi, U. Sennhauser, U. Straumann & C. Urban. Sub-pixel porosity revealed by x-ray scatter dark field imaging. *Journal of Applied Physics*, 110, 044912, 2011.

[2] T. Lauridsen, M. Willner, M. Bech, F. Pfeiffer & R. Feidenhans. Detection of sub-pixel fractures in X-ray dark-field tomography. *Applied Physics A*, 121, 1243-1250, 2015.

[3] E. Meyer, R. Raupach, B. Schmidt, A.H. Mahnken & M. Kachelrieß. Adaptive Normalized Metal Artifact Reduction (ANMAR) in Computed Tomography. *IEEE Nuclear Science Symposium Conference*, 2560-2565, 2011.

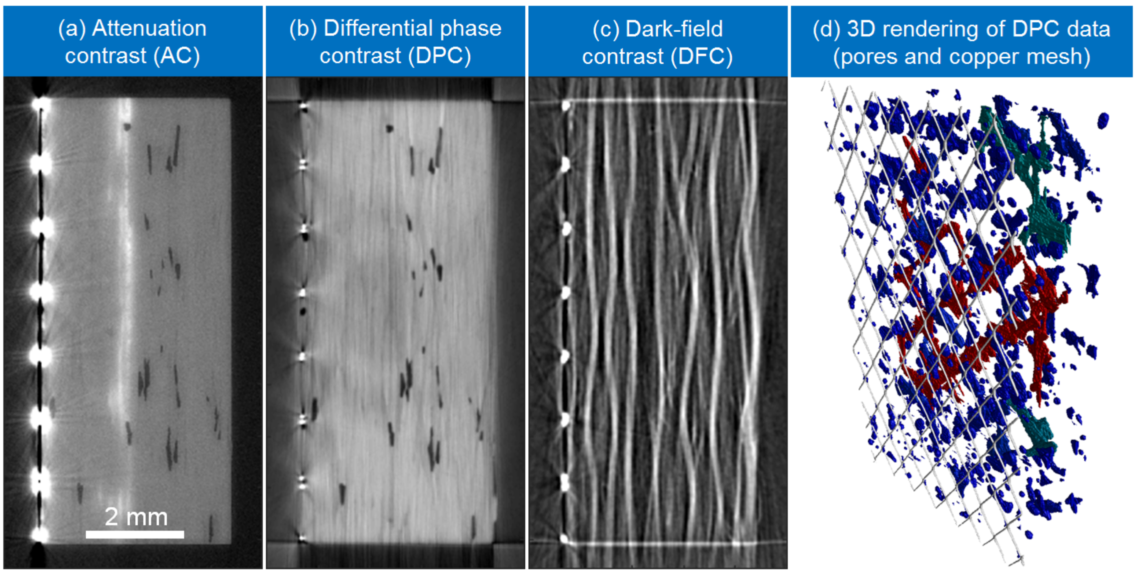

Figure 1: Axial slice images acquired with RayScan 250E are shown in (a), DPC and DFC data acquired with SkyScan 1294 in (b)-(c) and a 3D rendering of DPC data showing segmented pores with the copper mesh in (d).