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Published in:
Proceedings of the 14th euspen International Conference

Publication date:
2014

Document version
Early version, also known as pre-print

Citation for published version (APA):
Angel, J. A. B., Lauridsen, T., Feidenhans'l, R. K., Nielsen, M. S., & De Chiffre, L. (2014). Using grating based X-ray contrast modalities for metrology. In *Proceedings of the 14th euspen International Conference: 02/06/14 06/06/14, Dubrovnik, Croatia* (euspen ed., pp. 157-160). Dubrovnik, Croatia.

Using grating based X-ray contrast modalities for metrology

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Keywords: Coordinate Measuring Machine (CMM), X-ray Computed Tomography (CT), Grating-interferometer Based Imaging (GBI), Parametric errors.

Abstract

Traditionally, segmentation between multi-materials in CT is only available for cases, where material densities are not close to each other. A novel method called GBI offers a new possibility to overcome this problem, and was evaluated with respect to its metrological performance by comparisons to traceable measurements. The measurement results show that further development related to stability issues on the used CT is needed to create a metrological tool using GBI.

1. Introduction

CT is especially of great interest because of its unique advantages for material analysis and non-destructive-testing (NDT) compared to other NDT measuring methods. CT makes it possible to inspect faults and measure inner structures with high geometrical complexity. Traditionally, segmentation between multi-materials in CT scanning is made by using different techniques of edge detection and threshold algorithms, but these are only available for multi-materials where their densities are not close to each other [1]. A novel method called GBI overcomes this problem [2]. In this paper, GBI was evaluated with respect to its metrological performance by comparisons to traceable measurements acquired from a tactile CMM.

2. Developed reference artefacts

The parts for the experiments were selected with regard to dimensional limitations (field of view = 50 mm x 25 mm) and X-ray energy of the applied CT scanner (atomic number of the artefact, $Z < 20$). Tests were performed on 10 mm high cylindrical multi-material assemblies consisting of male and female parts in three different combinations, including a combination with approximately same densities. Polypropylene PP (density ρ = 0.905 g/cm³) was used for the male parts and PP, polyoxymethylene POM (ρ = 1.415 g/cm³), and polyethylene PE (ρ = 0.955 g/cm³) were used for the female parts. Furthermore, a 15 mm high step cylinder made of POM was selected to investigate parametric errors as beam hardening on internal dimensions in GBI [3]. All reference parts were manufactured by turning. The selected geometrical features were inner (ID) and outer (OD) diameters (see Figure 1), and both were measured from circles and compared to traceable CMM measurements. The step cylinder was measured from top to bottom at equidistance slices, where the first position (ID1 and OD1) refers to the top.

Figure 1: From left to right: PP-PE assembly, assembly sketch with measurands, POM step cylinder, and step cylinder sketch with measurands.

3. Experimental set-up

GBI is selected, because the technique demonstrates that it is possible to distinguish fine details in soft materials, which are indistinguishable in standard CT [4]. The used GBI is a prototype from Niels Bohr Institute. A GBI consists of three gratings, see Figure 2. A detailed description of the GBI process can be found in [2]. The GBI method generates dark field, phase contrast and transmission images.

Figure 2: Experimental set-up at Niels Bohr Institute. From left to right: X-ray source and source grating (G0), rotary table and step cylinder, phase grating (G1), and analyzer absorption grating (G2) followed by a detector.

4. Dimensional measurement results and image analysis

The reconstruction of the 2D X-ray images and data analysis of the tomograms were performed using VolumeGraphics software. Furthermore, image analysis on profile plots and gradient plots were performed on single projections using SPIP software. The images of single projections clarify that it is possible to distinguish between assemblies with approximately same densities using the dark field, see Figure 3.

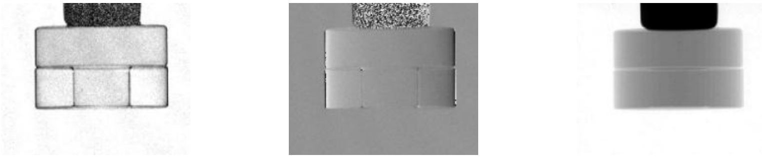

Figure 3: Example of single projections for assembly with the combination PP-PE. From left to right: dark field, phase contrast, and transmission images.

The acquired parametric errors for the step cylinder can be used for calculating the edge correction terms for internal and external features. Corrections of scale errors are realized by applying linear regression for the tomograms of the transmission images (see Figure 4), where the deviation from CMM values increases with increasing diameter size. For the inner geometries, the deviation from CMM values decreases in a small degree with increasing wall thickness, which could be due to combined artefacts as beam hardening, edge correction, and scale error correction. Noise and changed scale error corrections are detected on dark field and phase contrast images for both features. Challenges related to stability issues made it impossible to generate tomograms for the assemblies, where the metrological performance is evaluated based on single projections with deviations in the range of 36-286 µm. Due to noise on the dark field tomograms, it was not possible to obtain a proper comparison of metrological performances between transmission and dark field techniques. Future work should quantify the influence of dark field techniques in surface determination, as they are typically considered unsuitable for dimensional measurements because they alter borders significantly to make them visible.

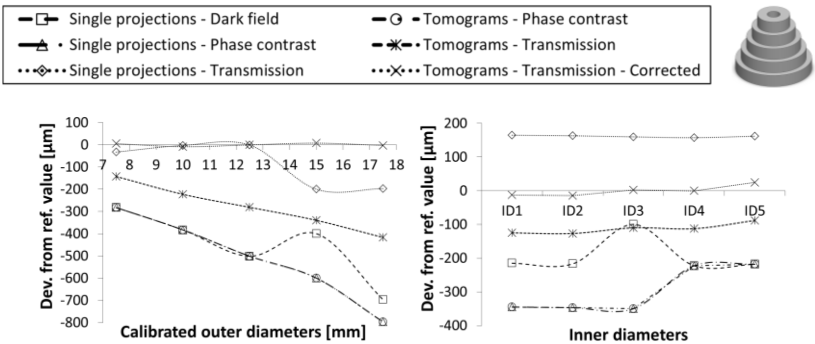

Figure 4: Step cylinder: dimensional errors on outer diameters (left), and dimensional errors on the inner diameters measured from top to bottom (right).

5. Conclusions

The images clarify that it is possible to distinguish between multi-materials where their densities are close to each other using the dark field images. Measurement results show that further development related to stability issues on the used CT is needed to achieve a metrological tool using GBI.

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