INTRODUCTION

Generally, inspection of the carbon fibre reinforced composites with metal components is embraced due to significantly different attenuation coefficients of a metal and CFRP components. At least two snapshots have to be taken with different X-ray spectra for each CT projection to be able separate material components and/or to reduce so called metal artifacts. Related so called dual energy CT (DECT) method can be generally based on two principles:

- Utilizing two different X-ray tube spectra with significantly different X-ray potentials and X-ray beam filters, not special requirements for X-ray detector;
- Splitting of the X-ray spectra into two (or more) bands utilizing energy thresholds which are set on the detector side (it supposes that detector has this ability as WidePix has). X-ray tube spectra can be shaped by the tube voltage and/or by X-ray beam filtering.

Inspection of the honeycomb part with metal core and CFRP skin

Honeycomb sample inspected has two basic components: CFRP skin and Al core. Artificial disbonding between skin and core was prepared on the one side. It was found that spectra for low energy (LE) and high energy (HE) X-ray beam have to be separated using appropriate voltage and X-ray beam prefiltering. CT measurement was done at five X-ray tube potentials of PerkinElmer Detector: 50 and 70 kV for LE, 130, 150 and 180 kV for HE. Al and Cu filters for LE and HE energies respectively. Influence of the tube potential on the tomographic reconstruction is illustrated below.

Material decomposition can be done utilizing weighted subtraction of the LE and HE reconstructed volumes (image based material decomposition):

\[ \text{DUAL LINE} = \text{weight} \cdot \text{LE} - \text{weight} \cdot \text{HE} \]

Weight factors for given HE and LE tube potentials have to be carefully chosen. Influence of the weight factor was tested on the one CT slice in figure below. Skin of the honeycomb is emphasized left; all components give similar signal middle and glue layer is emphasized right in this figure.

It was proven, that disbonding itself is hard to distinguish directly in 3D visualization at any tested X-ray tube voltage and applied thresholding.

Disbonding identification: It was found that identification of the disbonding can be simplified utilizing material decomposition mentioned above. LE at 70 kV and HE at 150 kV (related reconstruction depicted in two images above) were used for this purpose.

Material decomposition: attenuation coefficients and/or relative attenuation of low and high Z materials are significantly increasing with decreasing tube potential. Differences between attenuation coefficients are changing slowly for such behaviour for Carbon, Iron and Copper. Differences between attenuation coefficients are changing slowly for energies above 120 keV on other hand. Scattering effect began to be significant above this voltage value.

Concerning DECT instrumentation, it was found that spectra for low energy (LE) and high energy (HE) X-ray beam have to be expressed as much as possible using appropriate voltage and X-ray beam pre-filtering. Spectrum separation is necessary to improve material differentiation utilizing DECT tools. This differentiation is based on fact that differences between attenuation coefficients of low and high Z materials are significantly decreasing with increasing tube potential. Plot above illustrating such behaviour for Carbon, Iron and Copper. Differences between attenuation coefficients are changing slowly for energies above 120 keV on other hand. Scattering effect began to be significant above this voltage value.

DUAL SOURCE X-RAY μ-CT SETUP

- X-ray Tube: XRT100, spot size 1 μm (9 W)
- XRT150, spot size 1 μm (15 W)
- X-ray Detector: e-Line Sensor Detector Perkins+Elmer 256 x 256 px, 300 μm pixel pitch, 1024 x 1024 pixels, single photon counting detector
- XRT100, spot size 1 μm (9 W)
- X-ray Detectors: e-Line Sensor Detector Perkins+Elmer 256 x 256 px, 300 μm pixel pitch, 1024 x 1024 pixels, single photon counting detector
- XRT150, spot size 1 μm (9 W)
- X-ray Tube: XRT100, spot size 1 μm (9 W)
- XRT150, spot size 1 μm (9 W)
- X-ray Detectors: e-Line Sensor Detector Perkins+Elmer 256 x 256 px, 300 μm pixel pitch, 1024 x 1024 pixels, single photon counting detector
- XRT150, spot size 1 μm (9 W)
- X-ray Tube: XRT100, spot size 1 μm (9 W)
- XRT150, spot size 1 μm (9 W)
- X-ray Detectors: e-Line Sensor Detector Perkins+Elmer 256 x 256 px, 300 μm pixel pitch, 1024 x 1024 pixels, single photon counting detector
- XRT150, spot size 1 μm (9 W)
- X-ray Tube: XRT100, spot size 1 μm (9 W)
- XRT150, spot size 1 μm (9 W)
- X-ray Detectors: e-Line Sensor Detector Perkins+Elmer 256 x 256 px, 300 μm pixel pitch, 1024 x 1024 pixels, single photon counting detector

Acknowledgements:

This work was supported by the QVICTOR project funded by the 7th EU Framework Programme (FP7/2007-2013) under Grant Agreement No. 227-2QA-2012-314562, partially was also supported by project no. LO1219 under the Ministry of Education, Youth and Sports. The results were generated with support of Fraunhofer Development Center X-ray Technology E3T in Kaiserslautern, Germany. The projections were acquired and reconstructed using FlashHDL software Vixia X. The tomographic visualisations were done utilizing Volume Graphics GmbH software VGStudio MAX and by the open-source VisView 3.4 software. .