Visualization and defect detection of carbon-fiber reinforced plastic (CFRP) bike components with several commercial diagnostic x-Ray modalities

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ABSTRACT:
In this project we investigate the capabilities of three different commercial diagnostic x-ray units. The aim of this work was to illustrate the feasibility of visualizing entire components and structural defects to determine future applications in nondestructive analysis for the tested equipment.
To make other use of these technologies we had to find well defined acquisition geometry and exposure parameters. Apart from that we produce bias on physical size, spatial representation or inadequate image quality of the scanned structure.
The results show that component defects could be detected in the computed tomography and mammography images. The expected accuracy was not achieved with the computed radiography system and need to be further investigated for this purpose. However, the visualization of CFRP bike-components can be done with digital mammography, Computed Tomography and Computed Radiography Systems.

1 INTRODUCTION

Carbon fiber reinforced plastic (short carbon) is a common used material for high end bike components like frames, forks and wheels, etc. After highly mechanical stresses or road crashes there is a remaining risk for damage. In this case nondestructive analysis could help to detect different structural defects and ensure safety for further use.

In this project we investigate the capabilities of three different commercial diagnostic x-ray units [1]. The objective was to acquire images by a full field digital mammography, a Computed Radiography and a Computed Tomography Unit.

The aim of this work was to illustrate the feasibility of visualizing entire components and structural defects to determine future applications in nondestructive analysis for the tested devices. The physical properties of the examined material are unified to do imaging with commercial diagnostic units. Further on, preview papers can show that imaging is a helpful and necessary tool in this field [2]. Most of them are done with industrial CT-Units. Our approach was to point out the potential and the limitations of clinical x-Ray units [3,4].

2 METHOD

The main task was to develop a reliable protocol to get valuable images. For this purpose we identified two mayor topics – the equipment-object geometry and the x-Ray exposure parameters optimization.

To make other use of these technologies we had to find well defined acquisition geometry apart from that we produce bias on physical size and spatial representation of the image structure. Assuming that the spatial characteristics of a human body and a bike are similar we applied established medical principles. To stay aware of spatial deformation the acquiring object and the detector system was aligned strict parallel. To reduce magnification and preserve loss of systemic spatial resolution we used the maximum distance between the x-Ray source and the detector. Furthermore, to reduce geometrical deformation the object of interest was positioned as close as possible to the detector system.

The exposure parameters were also adapted. By optimizing the x-Ray exposure we focused on the milliampere-second product (mAs). This ensures a good image quality and high Signal-to-Noise Ratios. The kilo voltages peak (kVp) widely depends on the used modality. For Mammograms we decide to use 28 kVp, the computed radiographs were done with 44 kVp and the Computed Tomography images are taken with 120 kVp. We don't use any special x-Ray filter materials to manipulate the x-Ray spectrum.

3 RESULTS

There were no spatial deformations or exposure artefacts founded in the acquired images. Any tested x-Ray modality is unified to visualize CFRP bike-components (Figure 1, 3, 4, 5, 6).
Component defects could be detected in the Computed Tomography and mammography images (Figure. 1, 2).

The expected accuracy was not achieved with the Computed Radiography system and need to be further investigated for this purpose. However, the visualization of defect parts (Table 1) can be done with full field digital mammography and Computed Tomography Systems.

Table 1. Visualization and defect detection

Modality	Dimension	Scanned component	Visualization	Defects
Computed Tomography	2D/3D	Frame and extension parts	Yes	Yes
Mammography	2D	Fractured part	Yes	Yes
Computed Radiography	2D	Frame and extension parts	Yes	No

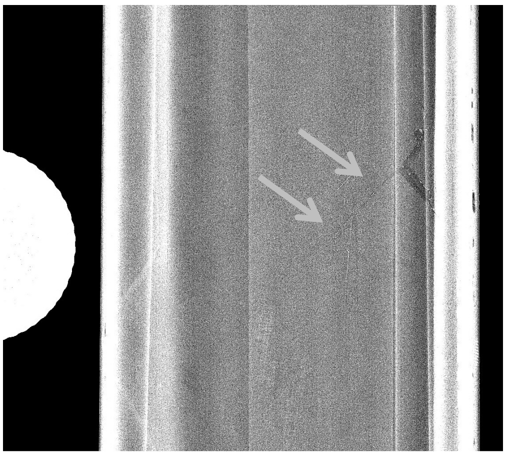

Figure 1. Mammography image shows a structural deformation after a crash – blue arrows marks the breaking line

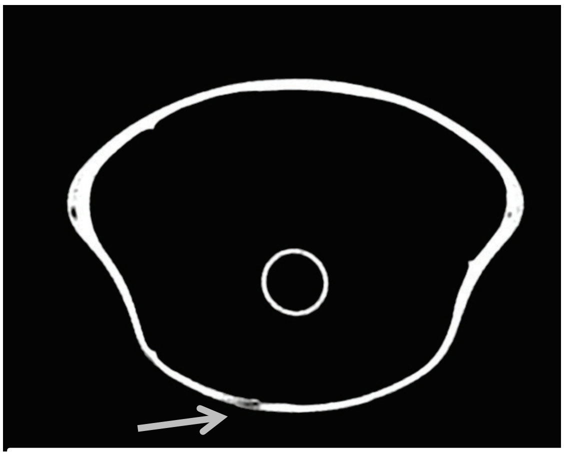

Figure 2. CT-Slice image shows a structural deformation after a crash – blue arrow shows the defect area

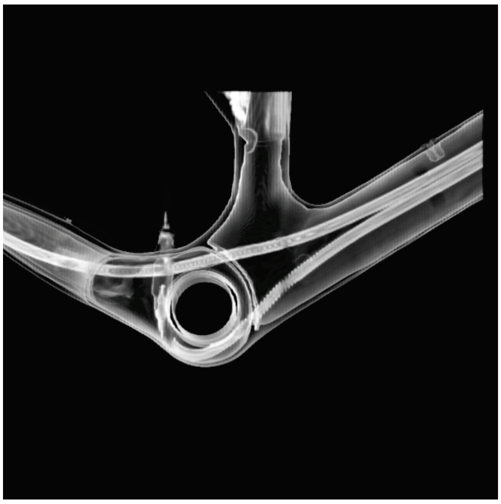

Figure 3. Rendered bottom bracket (CT-Image)

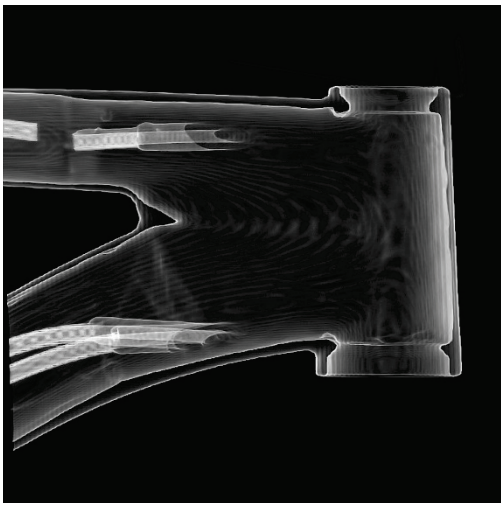

Figure 4. Head tube and wires (CT-Image)

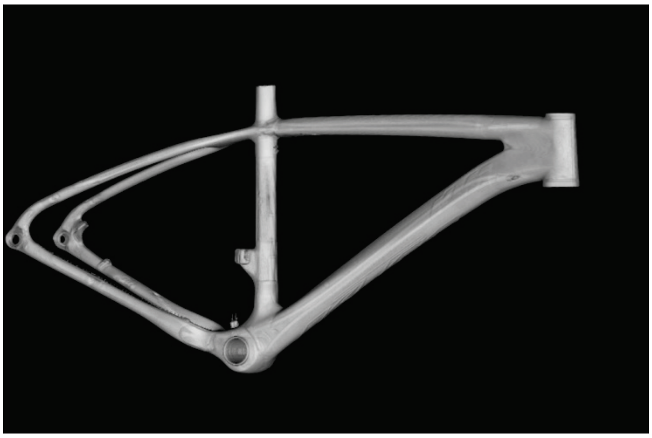

Figure 5. Surface rendering of a frameset (CT-Image)

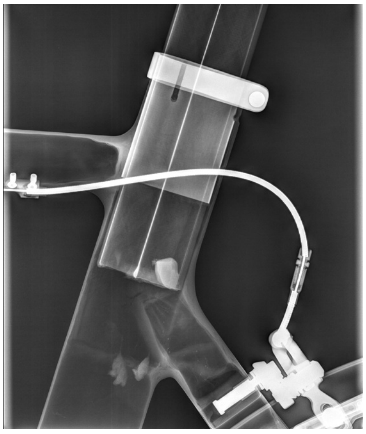

Figure 6. Computed radiography of a frame, seat post and brake

4 CONCLUSIONS

The results point out that the visualization of CFRP components could be done with the introduced equipment. The detection of structural defects is limited to digital Mammography and Computed Tomography units. Due to the rapid detector development there is an increasing potential to diagnostic x-Ray units in the field of visualize CFRP elements.

LITERATURE

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