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Determination of failure in composite structures on the microscale using non-destructive testing methods

Prototype of the Adwen AD 8-180 wind turbine in Bremerhaven, Germany *Courtesy: Helmut Gross*

The goal to maximize power extraction in wind turbines makes it necessary to increase the rotor swept area. Thus, rotor diameters increased from 20m in 1990 to 180m in 2017. However, the growing dimensions make the design of rotor blades a difficult task. An accurate prediction of their structural integrity is necessary to ensure a prescribed lifetime of 20 years. Therefore, a better understanding of the microscopic fracture mechanisms in fiber reinforced polymers becomes increasingly important.

Non-Destructive Testing of GFRP

A promising method to investigate microscopic fracture is non-destructive testing (NDT) by means of high resolution computer tomography (HRCT). It has the advantage of analysing the propagation of a crack without destroying the sample. This enables to investigate the propagation of a crack with un- and reloading scenarios. However, there are still some challenges related to the geometry, the scanning process and the postprocessing that all have to be adressed.

The geometry that is used on microscale level is a coupon sample made of glass/epoxy composite material. These are characterised by a cuboid shape and have a high aspect ratio. There are two main issues that have to be solved regarding the geometry: the mounting of the sample into the sample holder and the influence of the varying attenuation of the x-rays on the quality of the tomography.

Since it is not possible to identify a micro crack visually, the area of incidence has to be found in a low resolution scan. Furthermore it might be necessary to mount a clamp which opens the crack and improves the visibility in the tomography. Once the area of incidence has been identified, the sample needs to be unmounted to add further load on the sample and then remounted to look for crack propagation. Therefore a precise mounting system is necessary in order to relocate the area of incidence.

The quality of the generated tomography is important for the postprocessing steps, including segmentation of the material constituents, voids and cracks. If the tomography includes noise, an accumulation of fibers could be interpreted as one single fiber by the segmentation software.

Results

In a preliminary scan the possibilites of HRCT have been investigated.

In *figure 1* a glass fiber reinforced sample is illustrated. Besides the fiber and the matrix, various air bubbles are visible, which could be a spot for crack initiation.

In *figure 2* a carbon fiber reinforced sample is shown which has been loaded via a three point bending test. There are two fracture types visible in this figure, a kink-band with a delamination at its end.

Figure 3 illustrates the segmented sample from *fig 1* using the watershed method. The color map shows that some fibers could not be separated properly.

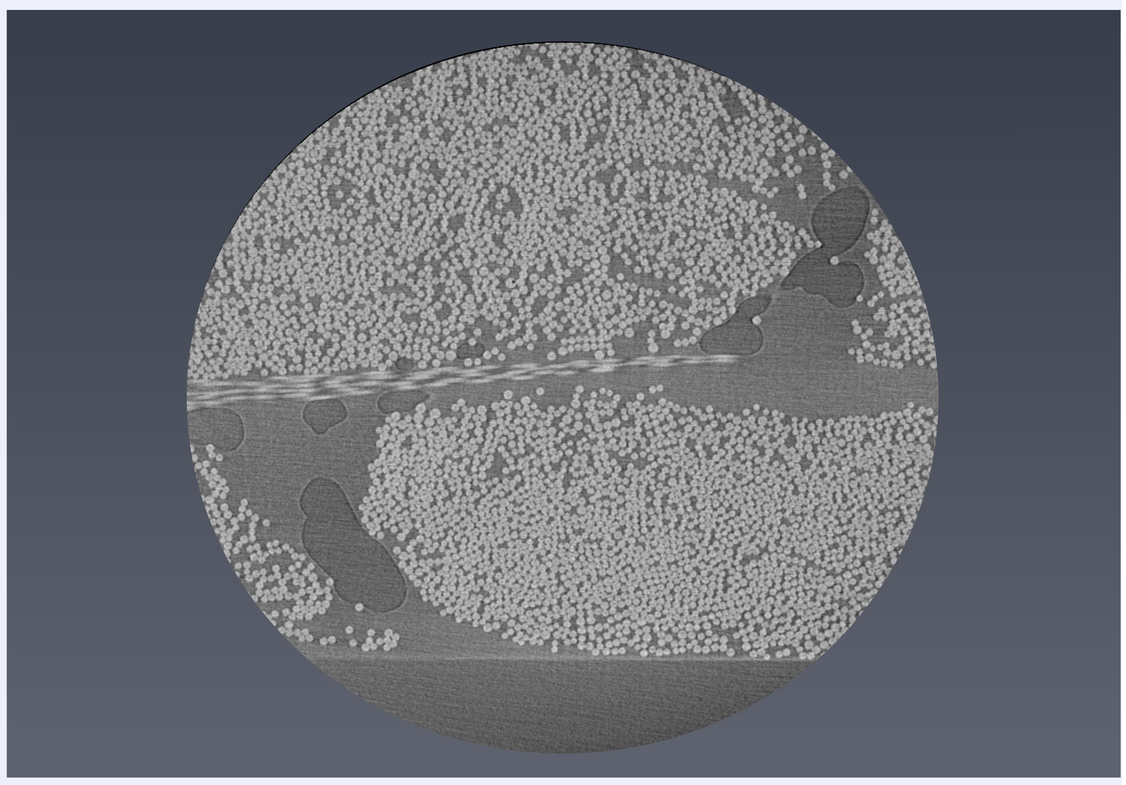

Figure 1: High resolution computer tomography of a glass/epoxy fiber composite including voids

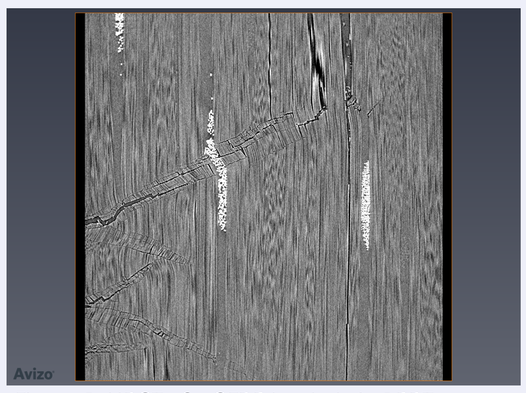

Figure 2: HRCT of a CFRP loaded via 3PBT

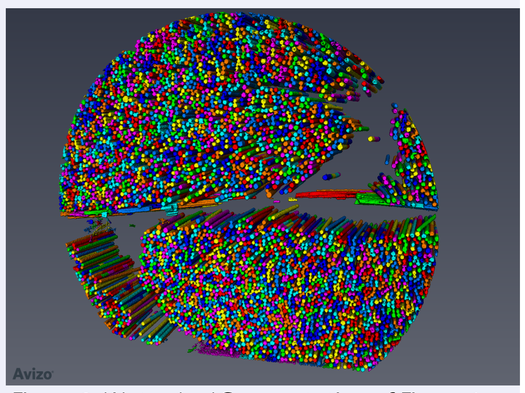

Figure 3: Watershed Segmentation of Figure 1

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