Using µ-CT for the measurement of fibre orientations in cellulose fibre reinforced PLA composites

Nina Graupner[1], Felix Beckmann[2], Fabian Wilde[2] & Jörg Müssig[1]

[1]*University of Applied Sciences Bremen, Faculty 5 - Biomimetics - Biological Materials, Neustadtswall 30, D-28199 Bremen, Germany*

[2]*Helmholtz-Zentrum Geesthacht, Center for Materials and Coast Research, Max-Planck-Straße 1, D-21502 Geesthacht, Germany*

This paper presents the measurement of cellulose fibre orientations in PLA composites. The knowlegde of fibre orientations is very important for the prediction of the mechanical characteristics of these composites. The investigated composites were produced by the injection moulding process described more specific in [1]. Representative, in this report the results are shown for 10 and 30 mass-% flax fibre reinforced PLA. Samples were prepared from dog bone shaped tensile test specimens with dimensions of approx. 5 x 5 x 4 mm^3. The µ-CT investigations were done at the beamline BW2 of the storage ring DORIS II at DESY. All tomograms were taken at a photon energy of 14 keV for optimum contrast. A spatial resolution of a = 7,8 µm was determined. For the evaluation of the data two directions in the volume were considered (xz = front view of the sample, yz = side view of the sample).

In contrast to polypropylene which displays a density of 0.9 g/cm^3 the difference between the cellulose fibres with a density of 1.5 g/cm^3 and a PLA matrix with a density of 1.24 g/cm^3 is very small. Despite the small density difference it is very difficult to differ clearly between the fibres and the matrix by the µ-CT. Hence a special method for the analysis of the fibre orientations in the composites must be developed. This was done based on the software Fibreshape (IST AG, Vilters, Switzerland) [2] in cooperation with the developer of the Fibreshape software Dr. Hubert Schmid. Therefore individual photographs taken by the µ-CT were loaded into the image analysing software Fibreshape.

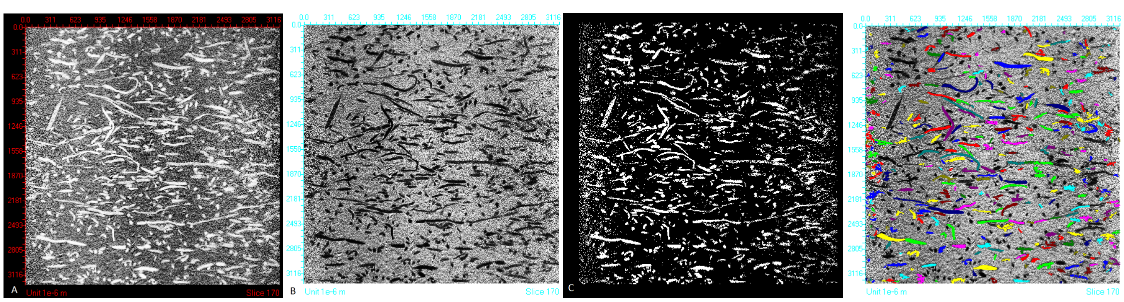

Figure 1: Image processing by Fibreshape. From left to right: orignial photograph, inverted photograph, inverted photograph with threshold, distinguished fibres in the inverted image.

For the orientation measurement with the Fibreshape system the originial photograph must be processed to an inverted image which is than binarized with the threshold and then used for the measurement. Distinguished fibre segments of the measurement are shown colored in the inverted image in figure 1.

In the case of the flax fibres each fourth slide taken by the µ-CT in xz and yz direction was analyzed in this way. The whole sample was divided into 5 layers while the xz direction shows the orientations in dependence of the sample thickness and the yz direction shows the results from the outer part to the inner part.

The processed data are shown in frequencies (in %) in figure 2 as bar diagrams in dependence of the 5 different layers for the 10 and 30 mass-% flax fibre reinforced PLA composites. The measured angle values are pooled in 10 ° increments.

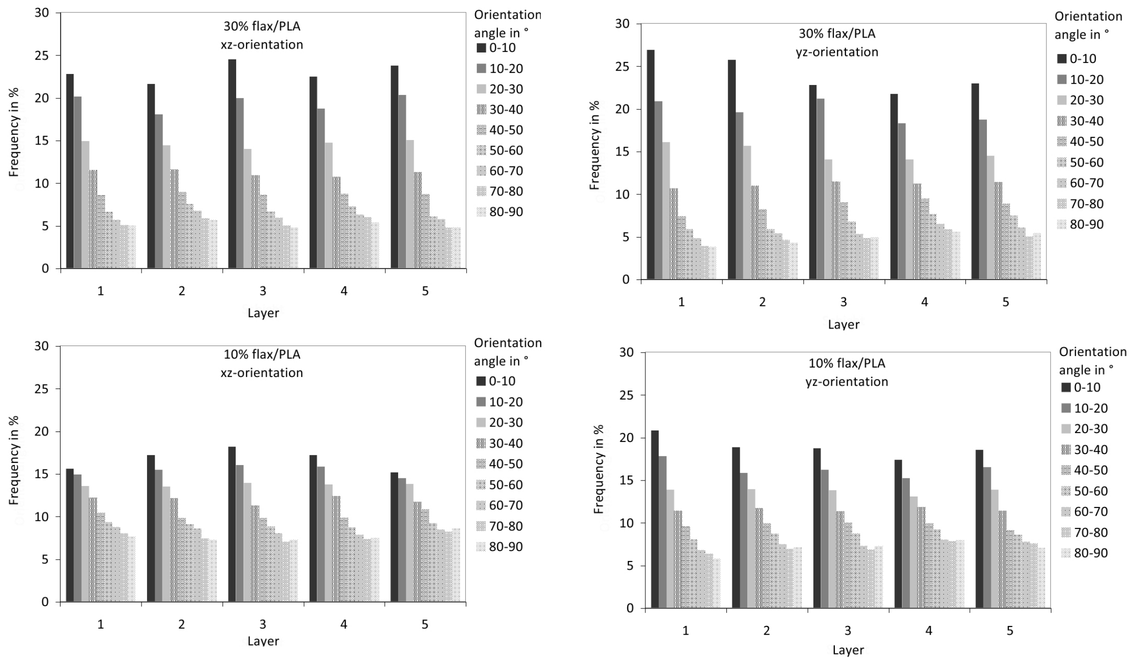

Figure 2: Measured fibre orientations in xz-orientation (left) and yz-orientation (right) of 10 % (top) and 30 % (bottom) flax fibre reinforced PLA composite.

Figure 2 shows that the main fibre orientation is in 0 - 10 ° direction for the investigated samples in xz- as well as in yz-orientation. Fibres oriented in length direction display the best reinforcement effect with regard to the tensile characteristics while fibres oriented in transverse direction can act as a kind of weak spots.

Bax and Müssig [1] observed an increasing tensile strength with a raising fibre load. They achieved tensile strength values of 42.3 ± 1.3 MPa for 10 % flax/PLA and 54.2 ± 4.6 MPa for 30 % flax/PLA. The neat PLA sample was measured with a tensile strength of 44.5 MPa. From the orientation measurements it is obvious that the fibres measured in the xz-orientation show in trend the best orientation (0 - 10 °) in the middle of the sample (layer 3). The analysis in yz-orientation displays in trend a better fibre orientation in the outer layers (layer 1) of the sample in comparison to the inner layers.

It is evident that the amount of fibres in the composites with a fibre load of 30 % is higher in length orientation compared to 10 % flax/PLA. As shown in the diagrams in figure 2 the fibre orientation in transverse direction is higher for the composites reinforced with 10 % flax in comparison to the composites with 30 % flax fibre reinforcement. These results fit well with the results of the mechanical measurements. No reinforcement effect was achieved for the 10 % flax/PLA with regard to the tensile strength. The tensile strength was measured below that of the unreinforced PLA sample. Hence, the bad tensile strength of 10 % flax/PLA is based on the lower amount of fibres which are oriented in length direction and the high amount of fibres which are oriented in transverse direction.

Despite of the low density differences between cellulose fibres and the PLA matrix the results have shown that fibre orientation measurement is well performable and evaluable with the µ-CT in combination with the Fibreshape image analysing software.

References

[1] B. Bax and J. Müssig. Impact and tensile properties of pla/cordenka and pla/flax composites. *Composites Science and Technology*, 68:1601–1607, 2008.

[2] H. G. Schmid, M. Dvorak, J. Müller, and J. Müssig. Characterizing flock fibers using quantitative image analysis. *Flock - English issue*, 30(1):6–12, 2004.