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How to capture centimeter-scale local variations in the pore space of paper: A benchmark study using μ-CT

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Though X-ray microcomputed tomography (μ-CT) is an established and versatile tool to determine the 3D microstructure of porous materials, it is still a major challenge to capture the degree of disorder and to determine the extent of heterogeneity in membrane-like materials [1,2]. Membranes, such as paper sheets, possess enormous aspect ratios. The formation of paper sheets yields a complex network of fibers that is characterized by strong local variations across the sheet, as found for fiber-based microstructures in general [3]. For properties associated with the pore space of paper, the impact of local in-plane variations, e.g. due to regions where fiber accumulations occur, is not well established so far. Hence, paper and particularly its pore space is an elegant test bed for designing and performing a μ-CT-based microstructure acquisition that is capable of revealing sheet-representative in-plane variations up to the centimeter range and variations in the sheet cross-sections within a few micrometers or less.

A framework to analyze local variations in the microstructure of paper sheets based on 3D image data is presented. To this end, a workflow to efficiently acquire a large set of highly-resolved tomographic image data is developed. In combination with statistical image analysis, this enables the quantification of local variations and pairwise correlations of morphological microstructure characteristics on length scales ranging from micrometers to centimeters. The microstructure characteristics considered in the present study are porosity, thickness, and mean geodesic tortuosity quantifying the length of the shortest transportation paths in the pore space [4]. The power of the presented framework is demonstrated by (i) quantitatively revealing the difference in terms of local structural variations between a model paper before and after unidirectional compression via hard-nip calendering as well as (ii) determining the field of view, which is required to reliably compute the local probability distributions of the considered microstructure characteristics. On the basis of our comprehensive data sets, relationships between structural differences and local densifications are elucidated. In particular, it is shown how calendering transforms local variations in sheet thickness into marked local mass density variations. The obtained results are in line with experimental measurements of macroscopic properties (basis weight, Bekk smoothness parameters, thickness, Gurley retention times) determined for the considered paper materials.

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Time Block Preference

Time Block A (09:00-12:00 CET)

References

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