Shape classification for wood based insulation material

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Summary: The micro-structure of highly porous insulation mats made of wood is investigated in order to further lower the thermal conductivity.

1. INTRODUCTION

Thermal insulation of buildings is crucial for stopping global warming. The insulation material market is still dominated by styrofoam products causing new problems in both production as well as disposal. Here, we report on image processing steps aiming at the microstructural optimization of wood based and thus renewable insulation products.

2. SAMPLES AND IMAGING

Samples are provided in duplicate: as non-processed material and as $300\,\text{mm}\times 200\,\text{mm}\times 100\,\text{mm}$ plates by the producer. For high resolution synchrotron computed tomography, cuboidal samples with short edge length 5 mm have to be prepared. This is extremely demanding due to the high porosity of 96 % and higher and the fact that mechanical strength is achieved by admixing a low proportion of bi-component fibers or wetting and drying the cellulose, only. Infiltration experiments resulted in residual pores dominating the X-ray absorption contrast. Therefore, a dedicated sample preparation method was developed at FIW.

The samples were imaged at ID19 of the European Synchrotron Facility (ESRF) in Grenoble, France. A photon energy of 19 keV (pink) was utilised with a single-harmonic undulator (u17.6 type) as a source. The resulting homogeneous wave front is excellently suited for propagation-based phase contrast imaging (camera-detector distance: 20 mm, detector pixel size: 0.65 µm). Single-distance phase-retrieval was applied (Paganin's approach combined with an unsharp mask) to allow for easy segmentation.

3. IMAGE PROCESSING

An indispensable prerequisite for optimizing the microstructure is a proper geometry model. This in turn usually requires the segmentation of typical microstructural objects from the 3D image data. Here, in particular the proportions of truly 3D chunks, chips, and individual fibers are of interest as these can be controled by tuning the production process parameters.

The gray value (16bit) images are denoised by a $5 \times 5 \times 5$ median filter. Binarization is then easily achieved by a global gray value threshold. Separation of objects is however not straightforward. The solid material forms essentially one connected component. Morphological transformations are not able to separate the objects as structuring elements have to be large enough to span over the large lumen areas. Using the lumen as a marker as suggested in [1] does not work neither as the lumen is not completely separated from the pore space in many

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cases - due to very thin walls not being completely captured in the 3D image as well as due to fiber walls being ripped during production. Fiber separation approaches as used in [3] do not work for the chips and chunks.

Here, we use therefore a tailor suited method based on locally measured densities of the intrinsic volumes [2]. More precisely, the specific surface area in cubic sub-volumes of an edge length slightly larger than the fiber thickness is considered. This value is higher in chunks, where the sub-volumes intersect with more than one layer of cellulose fibers compared to one layer thick chips and fibers. Analogously, but starting with smaller sub-volumes, chips and fibers are separated in a second step.

4. RESULTS

The solid material in a sub-volume is visualized in Fig. 1(a). The segmented objects are visualized using a false-color map in Fig. 1(b). This segmentation now allows to characterize the microstructure much more detailed. For instance, various shape characteristics can be determined as well as the orientation distributions of the three classes. Moreover, their proportions can be monitored with varying height within the mat. Finally, their proportion can be disclosed yielding valuable information for numerical simulation of thermal transport properties.

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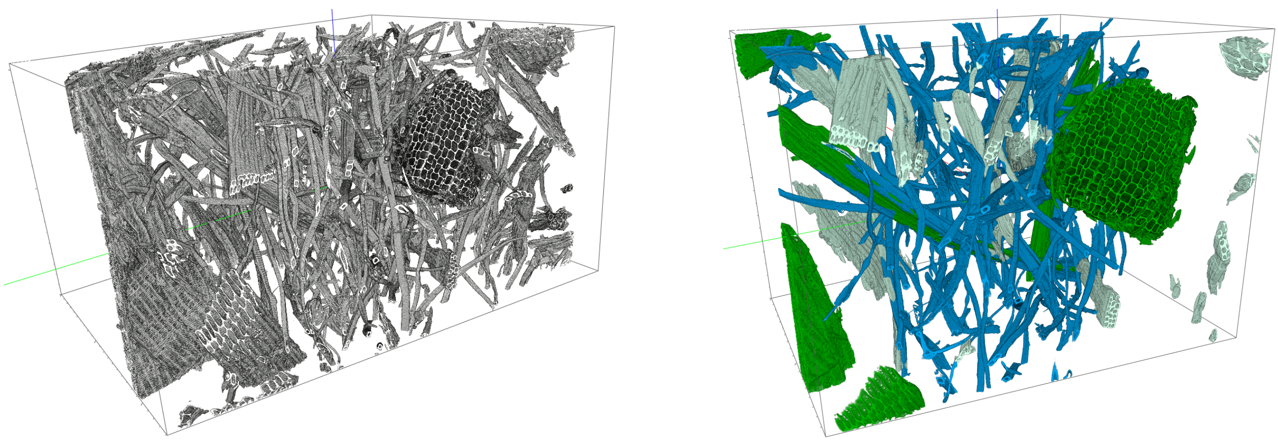

(a) Solid material   **(b)** Separation result

Figure 1: (a) Clipped volume rendering of the gray value image ($3691 \times 3691 \times 2048$ pixels). The visualization includes the entire cylindrical imaged volume of the scanned sample. (b) The segmented objects inside a rectangular sub-volume ($2700 \times 2700 \times 2048$ pixels) are separated into three categories: chunks, chips and fibers. It has been observed that the separation precision may vary for very specific cases where fiber and chips are placed close together over the greater area.