Representative Volume Element for Modelling the In-Plane mechanical Behaviour of Paperboard: Utilizing Microstructure from X-ray Tomography

Stina Starkenberg
stina.starkenberg@hotmail.com

Saga Wennerholm
sagawennerholm@hotmail.se

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Understanding the relation between the microstructure and mechanical properties of paper materials is crucial for optimizing their performance in practical applications. This study focuses on characterizing the microstructure of paperboard by analyzing the relation between the microscopic properties and its macro-mechanical response.

The aim of this project is to establish a workflow that transforms CT-scanned images of paperboard into a calibrated Representative Volume Element (RVE). A RVE is defined as the smallest volume that accurately captures the macroscopic behavior of the material and is independent on size and location of extraction. The workflow can be divided into four main steps.

1. Mapping CT-Images to a Virtual FE-Model: X-ray tomography images of paperboard are stacked to create a 3D volume. A finite element mesh is then generated, where each voxel in the image corresponds to an element in the mesh. These elements are binarized based on intensity values to distinguish between fiber and void.

2. Calculate Fiber Orientations: Fiber Orientations are identified and mapped to the model using structure tensor analysis that is based on analyzing intensity gradients. The fiber orientation is identified as the direction corresponding to the least change in intensity.

3. Calibrating Material Model: An automatic method is established to calibrate a transverse isotropic material model to the fiber elements. The fiber material parameters are iterative adjusted until the RVE's simulated stress-strain response aligns with experimental stress-strain response of paperboard.

4. Sensitivity Study: A sensitivity study is conducted to evaluate the effects

of RVE size, location of extraction, and resolutions on the accuracy and efficiency of the model.

The proposed workflow can convert X-ray images of paperboard into a virtual model that includes fiber orientations and calibrated material properties. However, the material calibration is complex, and the number of parameters to be calibrated with limited data makes it sensitive to the initially estimated parameters and the hardening model used.

The sensitivity study revealed that the RVE must be at least 0.33x0.33x0.12 mm to ensure size independence, although larger RVEs are required for achieving homogeneous properties. One way to model larger RVE's without increasing the computational time could be to use lower resolution images. However, a clear dependency on resolution was observed when voxels were binned together. Overall, further studies on the RVE's dependence on size, location and resolution are needed to draw statistically significant conclusions.