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MULTISCALE MODELLING OF PLANAR FIBER NETWORKS: CURRENT RESULTS FOR ELASTICITY AND STRENGTH OF PAPER, AND POTENTIAL APPLICATIONS TO RELATED MATERIALS

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Paper shows great variability in its mechanical properties, and interest in controlling these is probably as ancient as the use of paper itself. Hence, it is not surprising that various mathematical models for the mechanical interaction of fibers within the overall material paper have been proposed. However, none of these models explicitly accounted for the scale difference between the loads applied to the overall material and those acting on the level of the individual fiber. We recently filled this essential conceptual gap with the development of a new micromechanics-based linear elastic model for wood pulp-based paper, whereby a wood fiber micromechanics model was used to approximate the elasticity of 2D pulp fibers. The linear elastic model, which highlighted the importance of the fiber's anisotropy for the overall elastic behavior, was confirmed by various multiscale experiments [1]. The satisfying validation of our linear elastic model motivated us to expand it by introducing the shear strength of fiber-to-fiber bonds as a descriptor of macroscopic fiber network yield strength of corresponding paper sheets, and this strength model was also confirmed by various multiscale experiments [1]. We herein report an almost perfectly analytical multiscale model for wood pulp-based paper, now incorporating a pulp fiber micromechanics model and 3D pulp fibers which are randomly oriented in the paper plane. Our results show that we are very close to perfectly connecting all model input parameters with nano- and microscopic experiments on pulp fibers and their bonds on the one hand, and model predictions with macroscopic experiments on the elasticity, as well as yield strength of corresponding transversely isotropic paper sheets on the other hand. The observed similarities between pulp and, for instance, graphene or carbon fiber networks, as well as between the geometry of these fibers, similarities that are also reflected in the use of such expressions as graphene or bucky "paper", make us confident that the presented model constitutes an excellent platform for research on virtually any materials consisting of planar fiber networks, and composite systems incorporating them; not only with respect to their mechanical, but also electro-magnetic, optical, thermal, etc. behavior, which are all of interest for a growing number of applications.

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