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MODELING THE HYGROEXPANSION OF PAPER USING A 3D NETWORK MODEL

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Hygroexpansivity of paper is affected by several factors including fiber properties (longitudinal and transverse mechanical and hygroexpansion properties, fiber dimensions and curl), bond properties (area of contact), and network structure (fiber orientations, the degree of fiber-to-fiber bonding) [1]. However, due to complexity in the network structure, fiber and bond properties and the dependence between various parameters, it is not easy to relate the experimental results on hygroexpansion to the paper structure or fiber properties.

Recently, Bosco et. al. used a lattice method [2] which simplifies the network to an orthogonal cross where the thickness of each of the crossing segments is calculated based on the overall orientation of fibers in the network structure.

In the present work, paper is modeled as a 3D network of fibers. The geometry of the network is created by a deposition method in which the dimensions of each fiber including its length, shape and cross-sectional data are chosen based on the data from pulp characterization.

After creating the geometry, the finite element method is used to analyze the network. To discretize the geometry, fibers are meshed using beam elements, and fiber bonds are simulated using beam-to-beam contact elements. To simulate hygroexpansion, we introduce the stress-transfer relation on the bond level at the contact sites accounting for the angle between the crossing fibers, as well as their anisotropic mechanical and hygroexpansion properties. To verify the model, a response of the network to varying humidity is analyzed under free and constrained conditions and the results are compared with the results from a continuum model having the same geometry. It is shown that discretizing the network with beam elements and the proposed approach enables a tremendous saving in computation time without affecting the results noticeably. Combined with the plastic and creep model of fibers, the proposed model enables the analysis of such complex phenomena as development and release of dried in strains, as well as the response of the network to the through thickness moisture gradients.

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