UNIVERSAL BUILDING PLAN FOR WOOD: MICROMECHANICS-BASED PREDICTION OF ANISOTROPIC STRENGTH FROM COMPOSITION AND MICROSTRUCTURE

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Wood strength is highly anisotropic. Obviously, this anisotropy stems from the intrinsic structural hierarchy of the material: In all species, wood is composed of wood cells, which are hollow tubes oriented in the stem direction. The cell wall is built up by stiff cellulose fibrils with crystalline cores and amorphous surfaces, which are embedded in a soft polymer matrix composed of hemicellulose, lignin, extractives, and water. The elementary constituents of the wood cell wall exhibit tissue-independent stiffness and strength properties. The orientation of cellulose fibrils and tubular holes and the spatial gradation of porosity lead to the anisotropy and the inhomogeneity of the macroscopic material behavior.

This building plan was recently quantified in a multiscale homogenization scheme [1], allowing for prediction of the tissue-dependent (macroscopic) elastic properties of wood from its composition (volume fractions of elementary constituents and lumen/vessel porosities). As regards tissue-specific anisotropic strength properties, experimental investigations showed that (macroscopic) failure of wood is initiated by shear failure of lignin in the wood cell wall [2]. Corresponding local strain peaks in lignin are estimated through quadratic averages [3] over the strains in material phases representing microstructural entities, such as the cell wall or the elementary constituents. This gives access to prediction of tissue-dependent (macroscopic) failure surfaces for arbitrary deviations between principal material and loading directions.

Model estimates predicted from tissue-specific composition data agree satisfactorily with corresponding uniaxial and biaxial strength tests, across a multitude of different wood species and tissues. This confirms the paramount role of lignin as strength-determining component in wood.

References

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