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An anisotropic elastic constitutive model for wood with hygroscopic swelling in finite strains

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The use of timber as a construction material goes back several centuries. Recently timber products used in constructions has rapidly changed due to, sophistication in production of timber products, improved connections and assembly methods at sites. The structure of wood show orthotropic behavior, constituting three orthogonal material directions, i.e. the longitudinal (l), the radial (r) and the tangential (t) directions. These directions influence the physical and mechanical properties of wood, such as, strength, stiffnesses, the diffusivity and permeability, and the swelling/shrinkage properties due to moisture content variations. The properties of wood in these orthotropic directions have been well studied.

However, depending on from which part of the log a timber element is cut and on the purpose of its use in different parts of a building system, i.e. as a lamella in Glulam beams/columns, in cross laminated timber (CLT) or in different configurations at connections, the timber element can be exposed to loading in arbitrary directions and the deformations are not always small. One major issue is the rolling shear when wood is loaded perpendicular to the fiber directions either in compression or in shear. This has been observed to constitute greatly in failure of wood-products [1].

In this work an anisotropic non-linear hyperelastic constitutive model for wood is derived. The orthotripic material directions of wood are represented by three unit direction vectors that deform in finite strains by following the deformation gradient. The longitudinal and tangential direction vectors deform following a curved plane described by the annual rings, whereas the radial direction deform as a vector perpendicular to this plane, allowing the description of rolling shear dependent on the material orientations. An expression of Cauchy stress is derived together with the non-linear stiffness matrix [2]. Swelling due to moisture is accounted by introducing a multiplicative split of the deformation gradient. A two dimensional test example is implemented using the finite element method (FEM) and used to study the performance of this model in simulating rolling shear in wood.

References

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