Micromechanics of single wood fiber; testing and modeling

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ABSTRACT

There are numerous experimental studies showing the behavior of single wood cells in tension. All these experiments indicate the tensile behavior of single wood cells is complex and cannot be described by a simple linear elasticity. On the other hand, estimation of the elastic properties of cell wall has been the subject of several researches using different approaches from 2-dimensional to 3-dimensional multi-scale modeling. In spite of these sophisticated approaches, These models can only predict the behavior of single tracheids in the elastic zone and no model exist to explain the complex stress-strain behavior of single wood tracheids after the yield point.

To gain insight into the complex behavior of single wood tracheid, wood tracheids were subjected to controlled cyclic tensile loading. The cyclic tensile load-extension curves show three distinct segments. The first segment is almost a straight line. At some level of loading, a yield point is observed and beyond this point the specimen undergoes large permanent deformations. In this segment, the specimen macroscopically behaves like an elasto-plastic material with positive hardening. However, the rigidity of the specimen after the yield point increase slowly as the load is further increased. The slope of the curve increases significantly (third segment) with no evidence of yielding occurring in this segment. Based on this experimental result, a micromechanical model was built to explain the elasto-plastic behavior of a single wood tracheid by occurrence of matrix degradation (yielding; mainly breaking of hydrogen bonds), local decrease of MFA and bonding hydrogen bonds of the hemicelluloses. In this model, two important hypotheses were made; first considered that the MFA are non-uniform along a tracheid and second considered the possibility of local degradation of the matrix (breaking and re-forming the hydrogen bonds). However, each of these hypotheses should be verified by experimentations.

The main objective of this work was to explain the underlying mechanisms underlying in the complex behavior of single wood tracheid under tension. It is concluded that successive damaging-reforming of the matrix and local reduction of MFA are possibly responsible for the complex behavior of wood tracheids.