Influence of the thermal treatment of wood on the mechanical parameters at macroscopic and nanoscopic length scale

Dieter Loidl and Stefanie Stanzl-Tschegg

BOKU University of Natural Resources and Applied Life Sciences, Institute of Physics and Materials Science, A-1190 Vienna, Austria

Introduction

The main benefits of a thermal modification of wood are improved dimensional stability and higher durability for the outdoor use. Usually, this is accompanied by a reduced mechanical performance (e.g. reduced strength, or higher brittleness) [1], which results from a partial degradation of the matrix components of the wood cell wall.

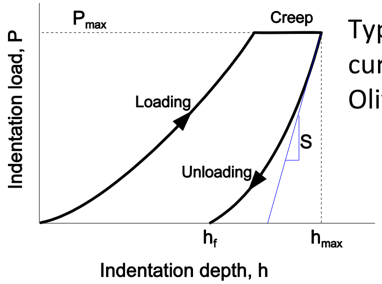
The mechanical properties in the longitudinal direction were investigated at different length scales of the hierarchically organised wood structure by means of instrumented indentation tests. A nanoindentation test system (Hysitron) was used at the cell wall level, and macroscopic indentation tests on the growth ring level were conducted with a servohydraulic universal testing system (MTS). The recordings of an instrumented indentation test yield a variety of mechanical properties from one single experiment. Besides the standard indentation parameters (e.g. hardness and elastic modulus), we evaluated viscoelastic properties and parameters related to the deformation energies.

Material

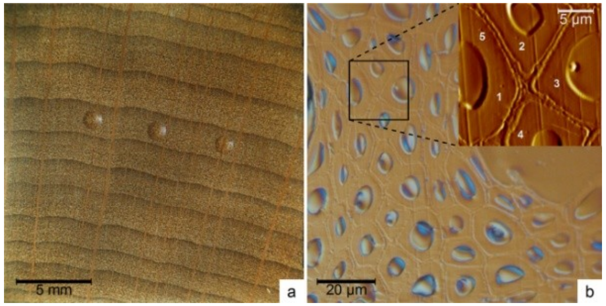
Type	Modification Temp. (°C)	Modification Duration (h)	EMC (%)	Density (g cm^{-3})
Reference	-	-	6.58 (0.06)	0.666 (0.004)
Weak	160	8	5.01 (0.05)	0.669 (0.009)
Strong	220	4	3.02 (0.02)	0.615 (0.005)

Parameters of the applied thermal modification. Equilibrium moisture content (EMC) and density of untreated and thermally modified wood samples (*Fagus sylvatica* L.) at a relative humidity of 30%.

Experimental



Typical indentation force-displacement curve with characteristic parameters of the Oliver/Pharr analysis



Micrographs of indents in the early wood region of a growth ring at a) the growth ring level and b) the cell wall level.

Results

Basically, the thermal treatment of beech revealed similar trends on the mechanical properties on the growth ring as well as on the cell wall level. The reduced modulus of elasticity increased only slightly (Figure 1), whereas hardness values significantly increased with increasing modification intensity on both length scales (Figure 2). We also observed a decreasing ductility index [2] and reduced viscous deformation energy (Figure 3) for increasing modification intensities on the cell wall and the growth ring level.

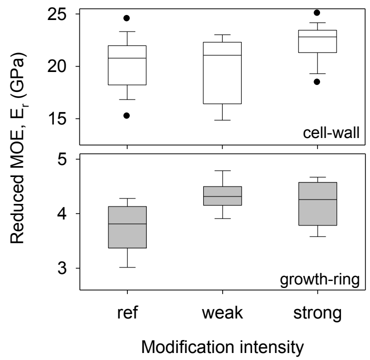


Figure 1

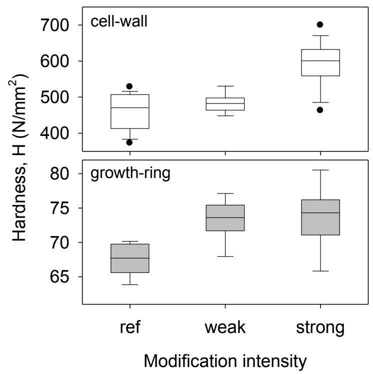


Figure 2

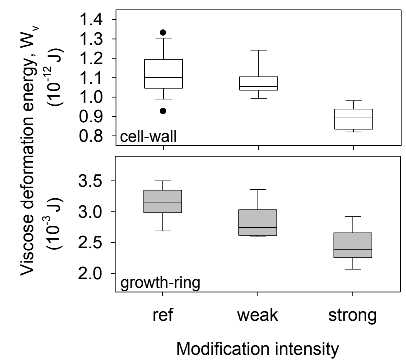
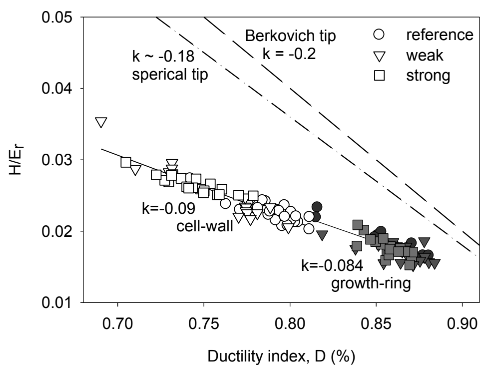


Figure 3

$$D = \frac{W_p}{W_t} = \frac{W_t - V_e}{W_t}$$ ... Ductility index

$$\frac{H}{E_r} = : \frac{W_t - V_e}{W_t} = : D$$

Comparison of indentation properties on different length scales in one single analytical framework.



Conclusion

The reduced EMC of thermally treated wood may be partly responsible for the observed effects, but cross linking reactions between the matrix components of the secondary cell wall [3] play an important role for the improvements of the mechanical parameter of thermally treated wood of beech in the longitudinal direction.

S. Stanzl-Tschegg et al. *Holzforschung* (2009) in print.

[1] P. Bekhta, P. Niemz: Effect of high temperature on the change in color, dimensional stability and mechanical properties of spruce wood. *Holzforschung*, 57 (2003), 539-546.

[2] M. Sakai: The Meyer hardness: A measure for plasticity? *Journal of Materials Research*, 14 (1999), 3630-3639.

[3] L. Salmen, H. Possler, J.S. Stevanic, S.E. Stanzl-Tschegg: Analysis of thermally treated wood samples using dynamic FT-IR-Spectroscopy. *Holzforschung*, 62 (2008), 676-678.