HNE Eberswalde
Hochschule für nachhaltige Entwicklung (FH)
Eberswalde University for Sustainable Development
University of Applied Sciences

Determination of dimensional stability of thermally modified beech and spruce wood

Lothar Clauder, Alexander Pfriem

Moisture sorption behavior below the fiber saturation point is a critical aspect of wood and wood products during their service life. Loss and uptake of moisture can be caused by fluctuating relative humidity and temperature leads to dimension changes. In this study, the effect of heat treatment on the dimensional stability of beech *(Fagus sylvatica L.)* and spruce *(Picea abies L.)* wood is compared to untreated samples as reference. The heat treatment at 180°C, 200°C and 220°C was conducted in N_2 gas atmosphere in a prototype kiln of approximately 0.5 m^3 capacity. Matched 10 specimens (10x20x20 mm^3) of each treatment intensity and 10 untreated samples as reference were tested (Schumann, 2011). The applied cycle test is based on oven-dry-water-soak-cycle-system (Rowell and Ellis, 1978). Results of a series of eight cycles are the best indicator of the effective achieved dimensional stability of a specimen. The schedule provides the following procedure for a single cycle: Oven drying at 103°C, once the mass is constant, water soaking at 50 mbar vacuum for 15 minutes. Then raising the pressure up to 8 bar and maintaining about 20 minutes. Afterwards keeping the specimens into the water for 24 hours till the mass is constant. The radial and tangential length change were measured by a dial indicator. The Anti-Swelling-Efficiency value (ASE) may be considered as a measure of the dimensional stability of wood.

eq. 1* max. swelling $$\alpha = \frac{l_{max} - l_{min}}{l_{min}} \times 100\,\%$$

eq. 2 mean max. swelling $$\alpha_{mean} = \frac{\alpha_{radial} - \alpha_{tangential}}{2}$$

eq. 3 Anti-Swelling-Efficiency $$ASE = \frac{\alpha_{mean\,reference} - \alpha_{mean\,modified\,sample}}{\alpha_{mean\,reference}} \times 100\,\%$$

Tab. 1: Max. swelling (eq.1), mean max. swelling-value (eq.2), ASE-value (eq.3)
* *l max = maximal length after water soaking;*
l min = minimal length after oven drying

The determination of the ASE (Tab.1) is based on the comparison of a treated specimen and an untreated specimen. The linear maximum swelling measure is determined in radial and tangential direction (eq.1) for each specimen. Thus, the mean maximal swelling (eq.2) is calculated. The calculation of the ASE value is based on the equation 3.

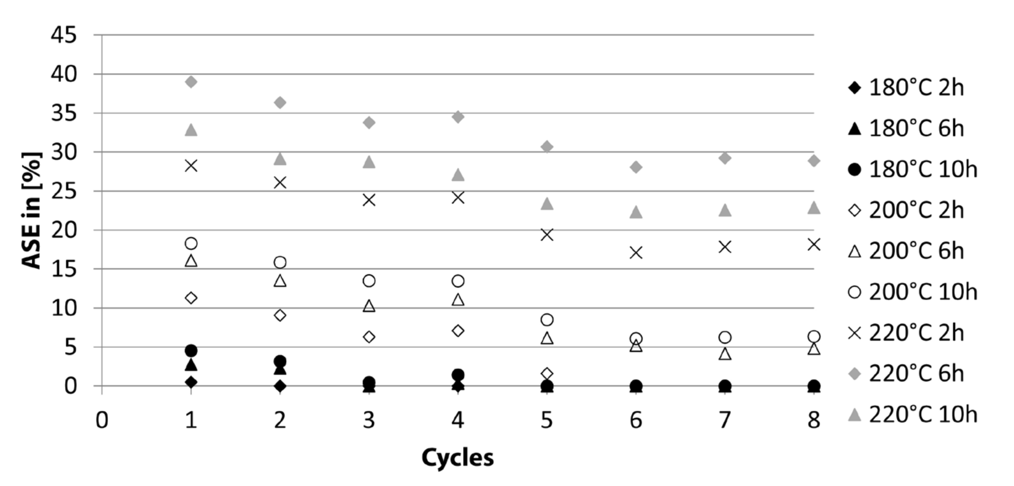

Figure 1. a) ASE values (spruce)

For specimens of both wood species the ASE values were calculated for each cycle as mean values in percent (Fig.1). The ASE values show the decline in swelling compensation during eight consecutive cycles, for both species. Therefor, in the advanced stage the effect of the dimensional stability of the thermally modified timber (TMT) is reduced by 12% for beech and 10% in the spruce compared to initial ASE after first circle.

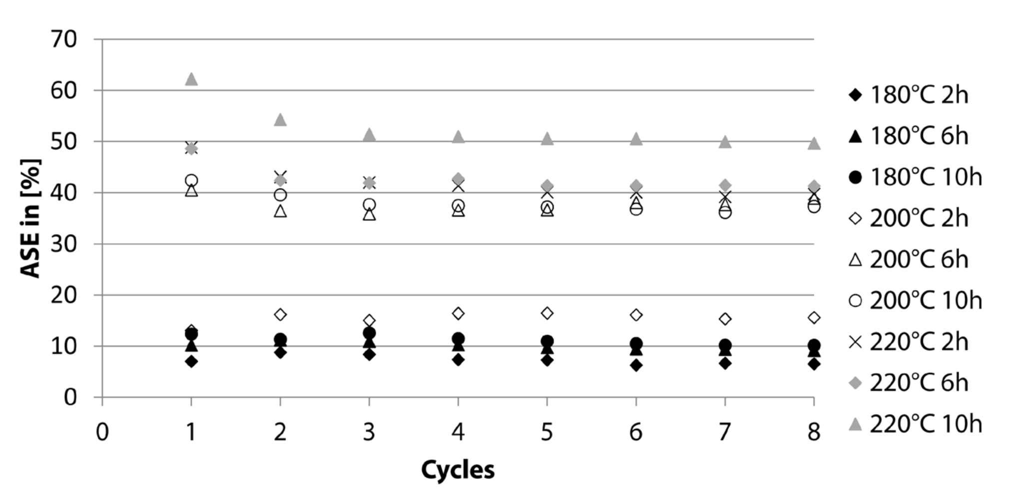

Figure 1. b) ASE values (beech)

The increase in ASE due to the gradual increase of temperature and duration of treatment can be explained by the thermal degradation of cell wall components. In the temperature range of 180°C to 220°C, increasingly hemicelluloses are degraded, whose OH groups are responsible for the high hygroscopic behavior of the wood. Burmester (1975) concluded that heat treatment of wood results in a high reduction in the hemicellulose content, and is thus an improvement of the dimensional stability of the wood. According to Fengel and Wegener (1989) hardwoods are thermally less stable than softwoods. This may explain why the ASE values of beech reached higher levels than those of spruce. The significant increase in ASE values from a treatment intensity of 200 °C and 6 hours duration for the samples of both species is even after the eighth cycle still detectable. The step-change in ASE values suggests an increased influence of the treatment period. By correlating the ASE with the process-induced mass loss (dm) Welzbacher (2007) specified a limit of dm for different treatment temperatures, beyond which no further increase in the ASE can be achieved by extending the treatment period. The ASE variation is detected in TMT, which can be used as a performance indication of the material in relation to its dimensional stability during the service.
Hygroscopicity of TMT was reduced compared to the untreated material. The results illustarte that die swelling compensation of TMT differs by a constant stress due to swelling and shrinkage of its initial value. This reduced swelling compensation is especially to be considered when evaluating the quality of TMT products for enhanced utilization as façade, flooring and other high-end joinery.

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Eberswalde University for Sustainable Development
University of Applied Sciences
Faculty of Wood Science and Technology
Friedrich-Ebert-Str. 28
16225 Eberswalde - Germany
Lothar.Clauder@hnee.de
Alexander.Pfriem@hnee.de

HNE Eberswalde
Hochschule für nachhaltige Entwicklung (FH)