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**Session 2**

# Effects of closed system hydrothermal treatment conditions on colour and hardness of European beech wood

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Hydrothermal treatment (steam-heat treatment) has been known for a long time as one of the most effective methods to balance colour differences and to improve the dimensional stability, the decay resistance and the durability of wood [1] but also as a useful tool in emerging methods of wood densification [2]. Along with the advantages, hydrothermal treatments are usually accompanied by intensive changes in the chemical composition and properties of wood, consequently increasing the interest in such information. Among other modifications, hydrothermal treatments result in colour changes [3, 4, 5] as well as degradation of all strength properties of wood [6]. Colour is determined non-destructively while mechanical properties usually require destructive methodologies in order to be evaluated. Hardness is related to other mechanical properties of wood and requires small specimens in order to be determined. For this reason, it is considered as one of the main indices of wood quality [7].

In an attempt to attain a relationship between treatment parameters (temperature and time) and colour as well as hardness of European beech (*Fagus sylvatica L.*) sapwood, laboratory-scale hydrothermal treatments were carried out in this study. Six hundred defect-free specimens with dimensions of 40mm x 40mm x 22mm were prepared from air-dried sawn boards which were climatised at normal climate (20°C, 65% RH) for at least 4 weeks. In order to facilitate hardness comparison between the treated and non treated ones, specimens were cut in pairs as explained in other works [8]. The specimens were subjected to hydrothermal treatments at 110, 140, 170 and 200°C for 10, 30, 60, 120 and 240min. The treatments were carried out in a 1,2l stainless steel reactor with steam temperature range of ±1°C. The treated and untreated test samples were then climatised at 20°C and 65% RH and were tested for the determination of Brinell hardness according to EN1534:2000 as proposed by Niemz and Stübi [9] using a Zwick 2020 Universal Testing Machine. The surface colour of all specimens was measured with a BYK Gardner tristimulus colourimeter with a 45/0 measuring geometry, circular measuring area of 20 mm in diameter, using a D65 illuminant and a 10° standard observer.

The results showed that hydrothermal treatments at temperature of 110-200°C resulted in a decrease up to 54,6 for $\Delta E^*$ and up to 60,6% for hardness. The higher treatment temperatures and the longer treatment times resulted to more intense changes. $\Delta E^*$changes at 110°C in the range of 10-240min followed logarithmic increase while at higher temperatures showed a more linear one. Moreover, multiple comparisons with one-way ANOVA (LSD, $\alpha$=0,05) showed that treatments at 110°C resulted to statistically significant (although marginally detected by the human eye) $\Delta E^*$ values for times up to 30min. The further increase of treatment time from 30 to 60, 120 and 240min did not cause significant further colour alteration. It was also found that treatment of 10min at 140°C resulted to the same ΔE* with treatments of 60, 120 and 240min at 110°C. Treatments at temperatures of 140, 170 and 200°C resulted to significant ΔE* values among all treatment intervals. It is obvious that the effect of hydrothermal treatment duration is milder than the effect of temperature. This effect seems stronger at higher treatment temperatures. The ΔE and L* values presented a severe reduction when the treatment temperature was 200°C and the duration was longer than 60min. The above specimens also showed high emissions of thermal decomposition products.

After similar statistical analysis, the hardness of the specimens showed significant reduction for hydrothermal treatments at 140°C and with durations longer than 60min but did not show significant change when duration increased from 120 to 240min. The above remarks can also be drawn from the related graph. Treatments at temperatures higher than 140°C induced more intense and duration dependent deterioration of wood hardness.

2-way ANOVA for independent samples showed that there is a significant influence of treatment temperature, treatment duration and interaction of both factors on the mean colour change ΔE* and hardness of the specimens. Lightness (L*) and ΔE* showed significant correlation (r=0,794 and r=-0,824 respectively, at the 0,01 level, 2-tailed) while the other colour parameters (a* and b*) were weakly to moderately correlated (r=-0,157 and r=0,489 respectively, at the 0,01 level, 2-tailed) to the hardness of the specimens.

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