Appearance and development of “sandwich effect” during beech timber drying in the conventional kiln

Goran Milić
Branko Kolin
Bojan Jeftić

University of Belgrade
Faculty of Forestry
Department of Wood Processing
Kneza Višeslava 1, 11000 Belgrade, Serbia

Background

- Beech (Fagus sylvatica, L.) - the dominant wood species in central and Southeastern Europe
- In Serbia, of all hardwoods used in wood industry, beech accounts for about 75% (according to “Srbijašume“ data)
- Beech timber - the main export product in wood industry in Serbia.
**Background**

- After log sawing, the beech timber in contact with oxygen and under the influence of increased temperature, starts turning its colour, i.e. it darkens, especially the core
- This phenomenon is called the “sandwich effect”
- Could be present already in air drying, and it is intensified when timber is artificially dried

**Objective**

- to obtain more information on the moment of occurrence and development of “sandwich effect”,
- and also to quantify the intensity of darkening of the inner core by colorimetric analysis
Material and method

- green beech timber
  - initial MC above 80%
  - nominal thickness 38mm
  - average width 150mm
  - length 2000 mm
- two test runs
- the laboratory kiln (0.8 m³)
- six boards in upper two rows of the stack

<table>
<thead>
<tr>
<th>Table 1. Heating up and conditioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature gradient of heating up</td>
</tr>
<tr>
<td>EMC during heating up</td>
</tr>
<tr>
<td>Conditioning temperature</td>
</tr>
<tr>
<td>EMC of conditioning</td>
</tr>
<tr>
<td>Conditioning time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Schedule of the active phase of drying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwoods (beech)</td>
</tr>
<tr>
<td>MC (%)</td>
</tr>
<tr>
<td>T (°C)</td>
</tr>
<tr>
<td>EMC (%)</td>
</tr>
</tbody>
</table>
Scheme of cutting test specimens

A, D – MC and color measuring
C – MC profile

Table 3. Sampling times

<table>
<thead>
<tr>
<th>Measurement No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements time from the beginning of drying (h)</td>
<td>0</td>
<td>24</td>
<td>48</td>
<td>72</td>
<td>96</td>
<td>144</td>
<td>192</td>
<td>240</td>
<td>End</td>
</tr>
</tbody>
</table>

Portable “Gardner” colorimeter

Positions of color measurement along the edge (red) and in the core (blue) (cross section of specimen)
**Results**

Sandwich effect was observed for the first time:
- after 144 hours in the first test run
- after 192 hours in the second test run

**Test run I**
- **Time 96 - 144 h**
- **t = 45 - 49°C**
- **EMC = 10.5 – 8.1%**
- **MC = 29 – 21%**

**Test run II**
- **Time 144 - 192 h**
- **t = 45 - 47°C**
- **EMC = 10 - 9%**
- **MC = 25 – 21%**
Results

Test run I
MC surface ~ 15%
MC core ~ 25-30%

Test run II

Results of colorimetric measurements

• done after couple of weeks, and after oven drying of samples

• 20mm head radius included also a great part of the darker portion of the sandwich

• the real colour differences are considerably higher than the obtained results
Results of colorimetric measurements

- still, clearly visible increase in the colour differences ($\Delta E$) can be seen, from the moment of sandwich detection to the end of drying
  - test run I: sandwich detection moment $\Delta E=1.95$
    - end of drying $\Delta E=3.54$
  - test run II: sandwich detection moment $\Delta E=1.27$
    - end of drying $\Delta E=2.47$

- $\Delta E$ increase through time mainly due to decreasing of $L$ (lightness) values for core layers measuring
**Before sandwich occurrence and at the end of drying**

<table>
<thead>
<tr>
<th>Board in test run I</th>
<th>Board in test run II</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
</tr>
<tr>
<td>$z = 96h; t = 44.8^\circ C$, EMC = 10.8%</td>
<td>$z = 96h; t = 41.2^\circ C$, EMC = 11.7%</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image 3" /></td>
<td><img src="image4.png" alt="Image 4" /></td>
</tr>
<tr>
<td>$z = 336h; t = 60.1^\circ C$, EMC = 4.3%</td>
<td>$z = 408h; t = 60.6^\circ C$, EMC = 4.8%</td>
</tr>
</tbody>
</table>

**Conclusions**

- The discolouration occurred in both test runs dried by the same schedules.
- It detected later than expected, in different periods, but at the same mean wood moisture contents of approximately 21\% (surface 15\%, core 25-30\%).
- Moisture content (and MC profile) is more important factor than time (of exposing to relatively high temperature).
- Sandwich detected at 45-49\^\circ C, showing that maybe higher temperatures, than usually recommended (30\^\circ C), can be applied for this thickness.
Thank you for your attention!