Drying Stress: How to Deal With It

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As wood dries, (below FSP, 30%MC), it shrinks.
But remember, wood shrinks both “as a material”, and as a “board”.

i.e.- when a “board” is at 40% MC, the “shell” is already below FSP, perhaps at 16% MC.
If shrinkage is “restrained”, because the “core” is still wet, while the “shell” is drying, stresses develop.

So, as wood dries it shrinks, as wood shrinks, stresses develop.
Wood Shrinkage Varies with Orientation, Density, and Species.
Hard Maple

Scanning Electron Micrograph
Courtesy of the SUNY ESF
N.C. Brown Center for Ultrastructure Studies

Red Oak

Scanning Electron Micrograph
Courtesy of the SUNY ESF
N.C. Brown Center for Ultrastructure Studies
Several “rules” about wood shrinkage:

• Dense wood shrinks more, because there is more wood material.
  – Latewood shrinks more than earlywood.
  – Maple and oak shrink more than pine.

• Shrinkage varies with orientation;
  – Longitudinal vs. transverse
  – Tangential vs. Radial
    • T/R ratio ~ 2/1
A good “general rule” about tangential shrinkage

• **Softwoods**, such as white pine shrink about 5 - 6 % from green to 0% -
  – ~ 1 % / 5.5% MC change

• **Hardwoods**, such as maple and oak shrink about 8 % from green to 0% -
  – ~ 1 % / 4% MC change

Longitudinal shrinkage of wood is very small, 0.1%

• Except for juvenile wood and reaction wood (compression and tension wood)
Longitudinal shrinkage of boards is very small.

- Except for -
  - boards with juvenile wood and reaction wood (compression and tension wood)
  - boards with sloped grain (which means there is a transverse component to the longitudinal orientation.)
Strength and Stiffness of wood depends primarily upon Density and Moisture Content

### Stiffness (bending // to grain)

<table>
<thead>
<tr>
<th></th>
<th>S.G.grn</th>
<th>Green</th>
<th>12%MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Pine</td>
<td>0.34</td>
<td>0.99</td>
<td>1.25</td>
</tr>
<tr>
<td>Hard Maple</td>
<td>0.56</td>
<td>1.55</td>
<td>1.83</td>
</tr>
</tbody>
</table>

*1,000,000 psi

*S.G.grn = dry weight (oven dry) / volume (green)*
### Strength (bending // to grain)

<table>
<thead>
<tr>
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<th>Green</th>
<th>12%MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Pine</td>
<td>0.34</td>
<td>4,900</td>
<td>8,600</td>
</tr>
<tr>
<td>Hard Maple</td>
<td>0.56</td>
<td>9,400</td>
<td>15,800</td>
</tr>
</tbody>
</table>

*S.G.grn = dry weight (oven dry) / volume (green)*

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So,

as wood dries it shrinks,

as wood shrinks,

stresses develop.
Development of Drying Stresses, Early in Drying

(a)

Dry shell – Tension
Wet core – Compression
Growth rings
Ray tissue

Development of Drying Stresses, Later in Drying

(b)

Dry shell – Compression
Dry core – Tension
Moisture Gradient during Drying

Moisture content (%)

Thickness

5 days  10 days  18 days

Moisture Gradient during Drying

Moisture content (%)

Thickness

28 days  36 days  50 days
Stress Gradient during Drying

Stress reversal in outside
Maximum tension in center
Final case-hardened state

Stress tension: compression
5 days 10 days 18 days
90 28 days 36 days 50 days
During “Stress Relief”,

- Moisture is added to the “shell” to cause it to try to swell against the core, relieving the stresses.

Stress Relief Conditioning

- High EMC (+4% hdwds) and Temperature
  - Adds moisture –
    - ACHIEVE **DESIRED EMC** QUICKLY!
    - AVOID OVERHEAT!
      - Cool kiln first
      - Reheat with spray
      - Low pressure steam
      - Water spray
      - Etc.
    - High temperature moves moisture faster
    - High temperature means wood is not as strong so stresses relieve more readily.
Equalization—Bringing the pieces of lumber in a kiln charge to nearly uniform moisture content. See Treatment, equalization.

Treatment, equalization—A controlled temperature and relative humidity condition used in a dry kiln at the end of drying to stop the drying of the driest boards while allowing the wettest boards to continue drying, thus reducing the moisture range between boards.
Table 7.32—Kiln sample moisture content and equilibrium moisture content values for equalizing and conditioning a charge of lumber

<table>
<thead>
<tr>
<th>Desired final average moisture content (percent)</th>
<th>Moisture content of dried sample at start (%)</th>
<th>Equilibrium moisture content in kiln (%)</th>
<th>Moisture content of wettest sample at end (%)</th>
<th>Conditioning equilibrium moisture content values (percent)</th>
<th>Softwoods</th>
<th>Hardwoods</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>9</td>
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Table 7.23—Traditional wet-bulb temperatures for equalizing hardwoods

<table>
<thead>
<tr>
<th>Final MC(^{a}) ((%))</th>
<th>Equalizing EMC ((%))</th>
<th>Wet-bulb temperature at various dry-bulb temperatures (, (^\circ F))</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (6)</td>
<td>3</td>
<td>140 150 160 170 180 190 200</td>
</tr>
<tr>
<td>6 (7)</td>
<td>4</td>
<td>92   101 110 120 130 140 150</td>
</tr>
<tr>
<td>7 (8)</td>
<td>5</td>
<td>99   108 118 127 137 147 157</td>
</tr>
<tr>
<td>8 (9)</td>
<td>6</td>
<td>105  115 125 135 145 156 167</td>
</tr>
</tbody>
</table>

\(^{a}\)Final MC values in parentheses are for faster drying when the highest quality drying is not required.
### Table 7.24—Traditional wet-bulb temperatures for conditioning hardwoods

<table>
<thead>
<tr>
<th>Final MC (%)</th>
<th>Conditioning EMC (%)</th>
<th>Wet-bulb temperature at various dry-bulb temperatures (°F)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>140</td>
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<tr>
<td>6</td>
<td>10</td>
<td>126</td>
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<td>7</td>
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<td>8</td>
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<td>130</td>
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<tr>
<td>9</td>
<td>13</td>
<td>132</td>
</tr>
</tbody>
</table>

**Conditioning treatment**—A controlled high temperature-high relative humidity condition used in a dry kiln after the final stage of drying to bring about a uniform moisture distribution in the boards and to relieve drying stresses.
Stress, drying—An internal force, exerted by either of two adjacent parts of a piece of wood upon the other during drying, caused by uneven drying and shrinkage, and influenced by set.

Tensile—Stress in the outer layers of wood during the early stages of drying when the layers are trying to shrink but are restrained by the still-wet interior region; also, the stress in the interior layers later in drying as they try to shrink and are restrained by the set outer shell.

Compressive—Stress found in the interior region of wood during the early stages of drying, caused by the shrinking of the outer shell; also, stress in the outer layers later in drying caused by the shrinking of the interior.

Stresses, relief of—The result of a conditioning treatment, following the final stage of drying, which causes a redistribution of moisture and a relief of the sets.
Thank you!