Drying Hardwood Lumber using Radio Frequency

Workshop – Regional Hardwood Initiative
September 21, 2010
Forestry Center, Fredericton

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James Kendall, Researcher (LTE)
Presentation outline

• RF drying basic principles and justification for hardwood drying

• Summary of RFV drying work that has been performed by FPInnovations and Hydro-Quebec between 2001 and 2008

• RF continuous drying idea

• RF continuous drying tests on hardwoods

• Technical and economical analysis to develop potential applications in hardwood sector

• RF continuous tests on low grade hardwoods

• Conclusion
RF drying basic principles and justification for hardwood drying

RF is a volumetric heating in the material versus convective and conductive ways that heat from the outside = less shrinkage variation = less constraint = drying speed can be increase = interesting for thick pieces

Water molecules (+ : H, - : O)

No stickers needed

Ref: www.radiofrequency.com
Work performed 2001-2004 with RFV lab kiln

- Principal conclusions with hardwoods
  - Excellent drying time for many products/species

<table>
<thead>
<tr>
<th>Product</th>
<th>RFV DT (days)</th>
<th>Conventionnal DT (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/4 red oak</td>
<td>4 to 7</td>
<td>150 to 180</td>
</tr>
<tr>
<td>4/4 hard maple</td>
<td>0.6</td>
<td>10-14</td>
</tr>
<tr>
<td>8/4 hard maple</td>
<td>6.2</td>
<td>30-35</td>
</tr>
</tbody>
</table>
Work performed 2001-2004

- Principal conclusions with hardwoods
  - Low MC gradients in thickness
  - Low residual stress
  - Natural color conserved
  - Low degrade
  - Final MC variation (between pieces) too important for hardwood products
    - Presorting/redrying strategies could help to improve final MC distribution
Work 2005-2008 (objectives)

- Continue to explore/identify drying potential applications for RFV technology
- Study redrying approach
- Develop technics/strategies to improve products quality (warpage, final MC distribution)
Explore/identify drying potential applications

• Conclusion, the best application for that technology
  – Thick pieces with not too small final MC variation
Re-drying approach study using RFV

Good conclusions and good payback for RFV redrying but:

- Better payback with conventional kilns
- Rehandling and management costs block the technics implementation
Solution, RF continuous redrying system at the planer mill

System advantages:
- Automatic pieces handling without piling
- Energy consumption lower than RFV technology
- Better final MC control (piece by piece)
- ROI possibly shorter than with RFV technology
Continuous RF VS conventionnal redrying

NO WEIGHT

Weight (3000 pounds)
Red oak 12/4 trial
Presentation of results Hardwood TAC spring 08
### Preliminary results for red oak 12/4

<table>
<thead>
<tr>
<th>Pièce #</th>
<th>Moisture content (%)</th>
<th>% Pces ±2% Avg MC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pièce #1</td>
<td>9.4</td>
<td>86</td>
</tr>
<tr>
<td>Pièce #3</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Pièce #4</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Pièce #5</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Pièce #6</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Pièce #7</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Pièce #8</td>
<td>6.3</td>
<td></td>
</tr>
</tbody>
</table>

AVG (%): 7.1
STD (%): 1.2
### Preliminary results for red oak 12/4

<table>
<thead>
<tr>
<th>Piece number</th>
<th>Coeur</th>
<th>Intermédiaire</th>
<th>Surface</th>
<th>TH moyenne</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>7</td>
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<tr>
<td>4</td>
<td>7</td>
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<td>5</td>
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<td>5</td>
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<td>7</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

**Moisture content (%)**

![Bar chart showing moisture content for different pieces and sections of red oak 12/4](chart.png)
Preliminary results for red oak 12/4
Drying trial on Hard Maple 4/4, color impact
Results presentation, Hardwood TAC Winter 09
## Results trial no.3 (color)

<table>
<thead>
<tr>
<th>Piece #</th>
<th>$\Delta E^*_{ab}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>1.04</td>
</tr>
<tr>
<td>12</td>
<td>2.87</td>
</tr>
<tr>
<td>13 (Beech)</td>
<td>2.67</td>
</tr>
<tr>
<td>14</td>
<td>0.36</td>
</tr>
<tr>
<td>15</td>
<td>0.62</td>
</tr>
</tbody>
</table>

If $\Delta E^*_{ab}$ value < 3, change in color cannot be seen by the human eye.

**Conclusion:** The technology has no impact on color.
Results trial no.3 (drying time)

2.4 HOURS!
Meeting of 6 industrials to discuss the potential of this technology

Energy cost to dry by RF

Energy cost for different initial MC to a final MC of 8%
Meeting of 6 industrials to discuss the potential of this technology

Equipment cost and electrode length (total) for:

DRYING APPLICATION FROM 60 TO 8% MC
Meeting of 6 industrials to discuss the potential of this technology

Equipment cost and electrode length for:

PRE-DRYING APPLICATION FROM 60 TO 30% MC
Meeting of 6 industrials to discuss the potential of this technology

Equipment cost and electrode length for:

RE-DRYING APPLICATION FROM 15 TO 8% MC

Equipment cost

Electrode length
Conclusions of industrial meetings

• For a 10 MMbf/year capacity hardwood mill operating 18 hours/day

  • The technology cost is estimated to:
    • 5 Millions $ for drying green to dry (60%-8%)
    • 3 Millions $ for pre-drying (60%-30%)
    • 1.5 Millions $ for re-drying (15%-8%)

  • The energy cost is estimated to:
    • 50$/Mbf for drying green to dry
    • 33$/Mbf for pre-drying
    • 12$/Mbf for re-drying
Conclusions of industrial meetings

- Even if industrials were surprised by the potential price of equipment, 5 on 6 want that we continue to work on development of this technology for hardwood applications.

- Interest for green to dry application
  - Determine if there’s a value added related to the technology, specially for low grade products.

- Interest for pre-drying
  - Determine what is the value added related to that practice.
  - Determine what is the maximum MC acceptable to stop stain development.

- Interest for re-drying
  - Determine final quality of the product.
Trial to determine if there is a value added using continuous RF drying technology to dry low grade hardwoods

20 twin boards dried by two technologies (continuous RF and conventionnal)

Initial grading

<table>
<thead>
<tr>
<th>Grade</th>
<th>HF</th>
<th>CONV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3S</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3B</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
Trial to determine if there is a value added using continuous RF drying technology to dry low grade hardwoods

Operation parameters

### Conventional

<table>
<thead>
<tr>
<th>Heat up</th>
<th>Dry bulb temp. (°F)</th>
<th>Wet bulb temp. (°F)</th>
<th>Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>92</td>
<td>4</td>
</tr>
<tr>
<td>Step 1</td>
<td>100</td>
<td>92</td>
<td>65</td>
</tr>
<tr>
<td>Step 2</td>
<td>105</td>
<td>95</td>
<td>4</td>
</tr>
<tr>
<td>Step 3</td>
<td>108</td>
<td>95</td>
<td>40</td>
</tr>
<tr>
<td>Step 4</td>
<td>115</td>
<td>95</td>
<td>24</td>
</tr>
<tr>
<td>Step 5</td>
<td>125</td>
<td>95</td>
<td>30</td>
</tr>
<tr>
<td>Step 6</td>
<td>155</td>
<td>120</td>
<td>53</td>
</tr>
<tr>
<td>Step 7</td>
<td>155</td>
<td>129</td>
<td>55</td>
</tr>
<tr>
<td>Step 8</td>
<td>155</td>
<td>145</td>
<td>1</td>
</tr>
</tbody>
</table>

### RF Continuous

- Power density: from 86 to 238 kW/m³
- Tension: 2.2 à 2.7 kV
- Conveyor speed: 6 in/minute
Trial to determine if there is a value added using continuous RF drying technology to dry low grade hardwoods

Results

<table>
<thead>
<tr>
<th></th>
<th>MC$_i$ (STD)</th>
<th>MC$_f$ (STD)</th>
<th>Drying time (hours)</th>
<th>Value before drying ($/Mbf)</th>
<th>Value after drying ($/Mbf)</th>
<th>Degrade (value loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF continu</td>
<td>56.4% (7.3%)</td>
<td>8.2% (0.8%)</td>
<td>3 à 5</td>
<td>507</td>
<td>455</td>
<td>52 $/Mmp</td>
</tr>
<tr>
<td>Conventionnel</td>
<td>57.7% (7.9%)</td>
<td>7.5% (0.5%)</td>
<td>276</td>
<td>492</td>
<td>485</td>
<td>7 $/Mmp</td>
</tr>
</tbody>
</table>

Value lost for dimension (shrinkage):
2 pieces for RF, 1 piece conventional
Trial to determine if there is a value added using continuous RF drying technology to dry low grade hardwoods

Problem that occurs during the tests with low grade material dried by continuous RF technology

Electrical arc in heartwood and decay wood that burns the wood
Conclusions on hardwoods RF continuous drying past performed works

- The main obstacle to implementing RFV technology in hardwood sector is the too large MC variation between pieces after drying.

- Drying by continuous RF can address the final MC variation problem because the moisture content is controlled piece by piece.

- Drying by continuous RF does not change the color of light woods as Sugar Maple.

- The first drying test with RF continuous technology on Sugar Maple has been realised in 2.4 hours.
Conclusions sur les travaux réalisés jusqu’ici sur le séchage des bois feuillus par HF

- Continuous RF drying of maple low grade material from green to dry does not add value to the product

- The two main applications that need to be studied in future work with hardwoods are:
  - Pre-drying of high grade material (to prevent stain on green wood)
  - Fast redrying of pre-dried material to give better flexibility and agility to the global transformation process