Suitability of Changbai Larch Plantation for LVL Products

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Abstract

The objective of this work was to examine the feasibility of Changbai larch (Larixolgensis Henry) plantation for manufacturing LVL products. Nine representative larch logs were sampled from each of four typical stands in the northern part of China. They were bucked and conditioned for veneer peeling. Veneer was then clipped, dried and stress graded with a production-line Metriguard veneer grader. Veneer properties were subsequently analyzed and benchmarked against common second-growth softwood species in Canada. All larch dry veneer sheets were further segregated into four E grades based on dynamic modulus of elasticity (MOE), and four LVL billets were manufactured from each E grade. The performance of those 16 LVL billets were evaluated in terms of flatwise and edgewise bending stiffness and strength. The results demonstrated that comparing with Canadian western hemlock (Tsugaheterophylla (Raf.) Sarg) and amabilis fir (Abiesamabilis (Dougl.) Forbes) with an average rotation of 68 years, Changbai larch has significantly higher veneer density and ultrasonic propagation time (UPT), and also higher veneer MOE. About 85% of larch veneer could be suitable for manufacturing 1.8E or higher grade commercial LVL. A high correlation existed in bending MOE and modulus of rupture (MOR) between the larch LVL and veneer for both edgewise and flatwise modes. Thus, the bending performance of larch LVL products can be accurately predicted with regard to veneer E grade.

Keywords: Changbai larch, Amabilis fir, Laminated veneer lumber (LVL), Modulus of elasticity (MOE), Stress grade, Veneer, Western hemlock
Introduction

Changbai larch (*Larix olgensis* Henry) is one of the most important commercial plantation species in the northern part of China. This species has a high growth rate and high survival rate due to its strong resistance to pests, diseases, and inclement weather (Liu 2004). With an increasing volume of plantations reaching a target rotation age, this species has become one of the major fiber stocks in China. Its logs are generally very knotty, which could affect the appearance grades and some mechanical properties of end products, so pulp has been the predominant industrial application for this species (Li 2001; Liu 2004; Sun and Pang 2005; Zhang et al. 2005), followed by lumber (He et al. 2009).

Opportunities exist to utilize plantation species, such as hybrid poplar (*Populus hybrids*), black spruce (*Picea mariana*), and aspen (*Populus tremuloides*), for manufacturing high-value wood composite products or engineered wood products (Wang 2001; Wang and Dai 2001; Knudson and Wang 2002, Knudson et al. 2002; Knudson et al. 2006; Wang and Dai 2005; Wang et al. 2010). Such potential products include glulam, structural composite lumber like laminated veneer lumber (LVL), parallel strand lumber (PSL or Parallam), veneer strand lumber (VSL) and oriented strand lumber (OSL) etc. and newer products such as cross laminated timber (CLT) for niche markets. The advantage of those products is that their performance is not necessarily limited by wood properties. They offer opportunities to convert low-value plantation logs to higher value next generation building products.

Traditionally, forest resources are mainly characterized through tests on clear wood and full size lumber (Zhang et al. 2005; Wang and Dai 2012). Veneer is a basic element for manufacturing plywood, LVL and PSL. Compared to dimension lumber, those veneer products have higher and more uniform stiffness and strength, greater dimension/dimensional stability and minimum defects. While growth characteristics of this larch species in China have been well documented, little is known about its veneer properties in relation to its site, stand management and tree growth. Virtually no effort has been undertaken to use this species for manufacturing veneer-based products, particularly LVL.

To maximize the value return from the larch plantations in China, a national research program was recently initiated to characterize this resource through veneering with regard to stand density, growth rate, and stem position and to determine its suitability for veneer products particularly LVL (Huang et al. 2012). As part of the initiative, the key objective of this work was to investigate the suitability of the larch plantation for LVL products. By analyzing the distribution of main larch veneer properties, a benchmark study can be done against other common softwood species to determine its suitability for LVL manufacturing and respective grade outturns. By manufacturing LVL billets from segregated larch veneer and conducting tests on their bending performance, the correlation between larch LVL and veneer properties can be established to identify the best product potential from this resource.

Materials and Methods

**Tree sampling and cutting.** In this study, the sample trees were obtained from Mengjiagang Forestry Center, Jiamusi, Heilongjiang province, China. This site is located in the...
Xiaoxinganling Mountain zone. The site belongs to the East Asian continental monsoon climate zone. Four typical stands were selected with varying initial spacing (or density), final density, and stand management practices. Nine representative trees were systematically selected from each stand, three each from large (30 cm), medium (25 cm), and small (20 cm) DBH classes, respectively. They were harvested, trimmed, and bucked. Six 1.25 m long bolts were systematically cut along the entire stem to peel 2.6 mm thick veneer. The live crown width, length, and DBH were measured from each tree before felling. After felling, the total height and diameter of the five biggest branches were measured as well as the diameter at different tree heights for calculating the tree taper. Clear wood specimens were also sawn from matched bolts for mechanical testing to permit comparison and validation and subsequent evaluation of product options (Huang et al. 2012). Table 1 shows the characteristics of the 9 sample trees from each stand with the mean DBH and tree height.

Table 1. Sampling schemes and stand characteristics of larch trees

<table>
<thead>
<tr>
<th>Stand no.</th>
<th>Initial density (trees/ha.)</th>
<th>Final density (trees/ha.)</th>
<th>Site index</th>
<th>Mean DBH (cm)</th>
<th>Number of trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3000</td>
<td>580</td>
<td>46</td>
<td>21.8(1.59)*</td>
<td>24.5(5.58)</td>
</tr>
<tr>
<td>2</td>
<td>4000</td>
<td>487</td>
<td>53</td>
<td>21.5(1.06)</td>
<td>23.2(4.54)</td>
</tr>
<tr>
<td>3</td>
<td>5000</td>
<td>305</td>
<td>53</td>
<td>22.3(1.05)</td>
<td>25.0(3.64)</td>
</tr>
<tr>
<td>4</td>
<td>6000</td>
<td>200</td>
<td>49</td>
<td>22.0(1.03)</td>
<td>26.8(4.80)</td>
</tr>
</tbody>
</table>

*Standard deviation

As shown in Figure 1, each tree was bucked into 6 segments with a mark from butt to top (crown) along the entire stem to indicate its stem position. Among which, the first segment (1300 mm from the butt) was right on the breast height for basic density measurement and veneer processing. Then, the 5 consecutive segments 2 to 6 were cross cut with a length of 2500 mm. After that, all segments were transported to the Chinese Academy of Forestry (CAF) in Beijing. In the pilot plant, each segment (from 2 to 6) was further cross cut to obtain 5 disks, starting from the bottom and labeled A to E for determining various wood characteristics. Disk A (30 mm thick) was used to determine chemical properties such as pH, acid, and alkali buffer values; disk B (30 mm thick) provided the sapwood and heartwood area ratio; disk C (50 mm thick) was used to observe anatomical symptoms such as annual ring width; section D (1250 mm long) was used to determine clear wood macro- and micro- mechanical properties, and section E (1250 mm long) was used for veneering.
Figure 1. Bucking and cross cutting of one sample tree

Veneer peeling, clipping, drying and grading. Each 1250 mm long section E (bolt) from segments 1-6 was transported to a plywood mill for veneer processing. The bolts were conditioned in a pond at 60 ºC for 48 hours before peeling with an industrial lathe equipped with a nose bar. The lathe settings were: horizontal gap = 2 mm, pitch angle = 89.5º, and vertical gap = 1.2 mm. The core drop size was 38 mm. The target veneer thickness was 2.6 mm (about 1/10 inch). Each veneer ribbon was clipped into 600 mm sheets in width sequentially from sap (bark) to core (pith). Then each sheet was coded with a number in combination with tree number, segment number, and veneer sheet number for easy identification. After that, each sheet was dried using a press dryer with a temperature of 120 to 130 ºC. A total drying time of about 15 min was used to achieve a target veneer moisture content (MC) of 3 to 6%, which is ideal for gluing. The dryer was opened once to evaporate steam after pressing about 7 min.

All dry sheets were shipped back to CAF in Beijing for nondestructive tests. Each sheet was fed through a full scale Metriguard 2800 veneer tester (Metriguard Inc. 2012). This tester uses a variety of property measurements for sorting veneer. These may include ultrasonic propagation time (UPT), density, or dynamic MOE. The density is measured by microwave cavity resonators. The data for each sheet were then downloaded from the tester for further analysis. The total number of veneer sheets was 2291 for density, UPT and dynamic MOE measurements. Note that the veneer dynamic MOE is computed as follows,

\[ \text{MOE} = \rho \times \left( \frac{1}{\text{UPT}} \right)^2 \]  

(1)

where \( \rho \) is veneer density and \( L \) is the span for the UPT measurement.

Data were first plotted for population cumulative distribution of each veneer property for the four combined stands. The comparison was made to benchmark this larch species against common
second growth western hemlock (Tsuga heterophylla (Raf.) Sarg) and amabilis fir (Abies amabilis (Dougl.) Forbes) with an average rotation of 68 years in Canada.

All 2291 veneer sheets were subsequently sorted into four E grades based on dynamic modulus of elasticity (MOE) with three E breakpoints, 10, 12 and 14 GPa for LVL manufacturing. The selection of those breakpoints was just for the convenience of veneer segregation since no stress grading rules are currently available.

**Pilot plant LVL manufacturing and testing.** An industrial single opening press (2440 mm x 1200 mm) was used to manufacture 15-ply larch LVL billets (1200 mm x 600 mm). A plywood phenol formaldehyde (PF) adhesive with a solids content of 55% was used to bond the veneer sheets. Four billets from each E grade were loaded into the press side by side for hot pressing. A total of sixteen LVL billets were made with the following manufacturing parameters: glue spread level, 150 g/m² per single glueline; pressing temperature, 145°C; target thickness, 37mm (thickness control); and pressing time, 40min. After unloading, all billets were stacked and stored for one week before cutting bending specimens. The bending MOE and modulus of rupture (MOR) were measured in both flatwise and edgewise modes in accordance with GB/T20241-2006 (China Standard Press 2006), which is equivalent to Japanese LVL Standard (JAS SIS-24 1993).

**Results and Discussion**

**Benchmarking larch veneer properties.** Table 2 summarizes the veneer properties in terms of four individual stands. For each stand, the total number of veneer sheets was also calculated, reflecting a measure of veneer yield. The same number of trees harvested from each stand resulted in different veneer yields, mainly due to the difference in the tree mean DBH (Table 1). The coefficient of variation (COV) ranged from 8.6 to 12.1% for veneer density, 7.0 to 7.9% for veneer UPT, 12.9 to 13.4% for dynamic veneer MOE. Comparatively, the stand 1 yielded the highest veneer density and MOE than the other three stands (p = 0.05). Based on Table 2, the within-stand variation seemed to be higher than the between-stand variation.

<table>
<thead>
<tr>
<th>Stand no.</th>
<th>No. of sheets</th>
<th>Density (g/cm³)</th>
<th>UPT (µs)</th>
<th>MOE (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>517</td>
<td>0.539</td>
<td>0.046</td>
<td>200.9</td>
</tr>
<tr>
<td>2</td>
<td>490</td>
<td>0.535</td>
<td>0.061</td>
<td>203.6</td>
</tr>
<tr>
<td>3</td>
<td>619</td>
<td>0.523</td>
<td>0.543</td>
<td>202.9</td>
</tr>
<tr>
<td>4</td>
<td>665</td>
<td>0.520</td>
<td>0.631</td>
<td>204.1</td>
</tr>
</tbody>
</table>

Figure 2 shows the density cumulative distribution function (CDF) of Changbai larch veneer in comparison with western hemlock and amabilis fir veneer. The data of hemlock and amabilis fir were cited from a recent hem-fir study with an average rotation age of 68 years (Wang et al. 2010). There existed a large variation in the veneer density for each specis. The larch veneer...
density generally ranged from 0.40 to 0.70 g/cm³, which is significantly higher than hemlock and amabilis fir (p = 0.05).

Figure 2. CDF of veneer density compared by species

Figure 3 shows the UPT cumulative distribution function (CDF) of Changbai larch veneer in comparison with western hemlock and amabilis fir veneer. The UPT is generally affected by grain angle, knots and other wood defects. There existed a large variation in the veneer UPT for each species. By comparison, the larch veneer had the highest UPT, followed by hemlock and amabilis fir veneer. This may indicate that the larch has a larger microfibril angle than the other two species.
Figure 3. CDF of veneer UPT compared by species

Figure 4 shows the dynamic MOE cumulative distribution function (CDF) of Changbai larch veneer in comparison with western hemlock and amabilis fir veneer. There existed a large variation in the veneer MOE for each species. By comparison, the larch veneer had the highest MOE, followed by amabilis fir and hemlock. On average, a conversion factor of approximately 1.10 can be used to link product MOE with veneer MOE using conventional pressing schedules with a panel compression ratio (CR) ranging from 7-13% (Wang and Dai 2001). Based on Figure 4, about 85% of the larch veneer from the four stands combined can be used to manufacture higher grade LVL, meeting 1.8E (12,411 MPa) or higher grade LVL requirements.

In summary, comparing with Canadian hemlock and amabilis fir (68-year old on average), Changbai larch has significantly higher veneer density and UPT, and also higher veneer MOE. Under the circumstance of such a large variation of veneer properties, veneer stress grading is deemed necessary for structural applications of the larch veneer.

Stress grading of larch veneer. Table 3 summarizes the properties of each E grade after sorting with the following three E breakpoints: 10, 12 and 14 GPa. There was a clear descending trend from E1 to E4 for both veneer MOE and density. Compared with the unsorted population, the within-grade variation of veneer MOE and density was significantly reduced, which is beneficial to manufacturing of consistent LVL products.
Table 3. Properties of larch veneer E grades

<table>
<thead>
<tr>
<th>Veneer E grade</th>
<th>MOE threshold (GPa)</th>
<th>Number of sheets</th>
<th>Dynamic MOE(GPa)</th>
<th>UPT (µs)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>E1</td>
<td>&gt;14</td>
<td>545</td>
<td>15.86</td>
<td>0.65</td>
<td>191.0</td>
</tr>
<tr>
<td>E2</td>
<td>12-14</td>
<td>1023</td>
<td>13.37</td>
<td>0.79</td>
<td>199.0</td>
</tr>
<tr>
<td>E3</td>
<td>10-12</td>
<td>628</td>
<td>11.21</td>
<td>0.54</td>
<td>210.5</td>
</tr>
<tr>
<td>E4</td>
<td>&lt;10</td>
<td>95</td>
<td>9.22</td>
<td>0.74</td>
<td>226.8</td>
</tr>
<tr>
<td>Population</td>
<td>Unsorted</td>
<td>2291</td>
<td>12.79</td>
<td>1.75</td>
<td>203.4</td>
</tr>
</tbody>
</table>

Correlation between larch LVL and veneer. Based on the measurement of final LVL thickness, it was found that the compression ratio (CR) of larch LVL was about 11-13%, which helps enhance the bending properties of LVL. Table 4 summarizes the bending MOE and MOR of larch LVL and veneer MOE. By comparison, LVL had a higher MOE than veneer for both edgewise and flatwise bending modes. The higher veneer E grades yielded higher LVL bending MOE and MOR.

Table 4. Properties of larch veneer and LVL

<table>
<thead>
<tr>
<th>Veneer E grade</th>
<th>Veneer MOE (GPa)</th>
<th>LVL MOE (GPa)</th>
<th>LVL MOR (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Edgewise</td>
<td>Flatwise</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>E1</td>
<td>15.79</td>
<td>0.53</td>
<td>19.53</td>
</tr>
<tr>
<td>E2</td>
<td>13.41</td>
<td>0.30</td>
<td>16.79</td>
</tr>
<tr>
<td>E3</td>
<td>11.01</td>
<td>0.35</td>
<td>12.86</td>
</tr>
<tr>
<td>E4</td>
<td>9.15</td>
<td>0.64</td>
<td>10.96</td>
</tr>
<tr>
<td>Total</td>
<td>12.34</td>
<td>2.55</td>
<td>15.73</td>
</tr>
</tbody>
</table>

Figure 5 shows the correlation between LVL edgewise bending MOE and MOR and mean MOE of veneersheets built into each billet. The correlation was excellent giving an equal $R^2$ of 0.91. Similarly, Figure 6 shows the correlation between LVL flatwise bending MOE and MOR and mean MOE of veneersheets assembled into each billet. The correlation was also good giving an $R^2$ of 0.90 and 0.82, respectively. The results indicate that the performance of larch LVL can be accurately predicted with regard to the veneer E grade.
Figure 5. Correlation between larch LVL edgewise bending performance and veneer MOE

Figure 6. Correlation between larch LVL flatwise bending performance and veneer MOE
Conclusions

A significant variation existed in properties of Changbai larch veneer within each stand and population. The within-stand variation seemed to be higher than the between-stand variation. Comparing with Canadian second growth hemlock and amabilis fir, Changbai larch had significantly higher veneer density and UPT, and also higher veneer MOE. About 85% of the larch veneer from the four stands combined could be suitable for manufacturing 1.8E or higher grade commercial LVL. A high correlation was found between the larch LVL and veneer in terms of both edgewise and flatwise bending modes. The results demonstrate that Changbai larch is suitable for manufacturing LVL products with higher grade outturns, and the performance of larch LVL is predictable in relation to veneer E grade.

Acknowledgements

This work was part of a research program sponsored by the Special Overseas Cooperation Fund for Chinese Academy of Forestry (CAFYBB2008008) and the National Natural Science Foundation of China (No. 30825034). The authors would like to thank FPInnovations for their cooperation. We sincerely thank Dr. Rongjun Zhao, Dr. Xinting Xing, and research assistants Weiwei Shangguan and Yali Shao for their participation in sampling trees and conducting clear wood tests. We also thank Dr. Dongsheng Chen for providing stand information. We further thank the staff from Sanli Company for their help in veneer peeling and the management team at the Mengjiagang Forest Centre for their assistance in field work and log conversion.

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