LUMBER FROM SMALL-DIAMETER TIMBER: DO ATTRIBUTES MEET MARKET DEMANDS?

Francis G. Wagner, Thomas M. Gorman, Keith L. Pratt, and Charles E. Keegan

ABSTRACT

Changing forest conditions and evolving management practices are impacting the raw material available to sawmills in western North America. The sawtimber harvested today is often small in diameter, includes sweep, and contains large proportions of juvenile wood. The purpose of this study was to assess warp, MOE, and grade of curve-sawn (sawn following the curve of the log) structural lumber produced from small-diameter Douglas-fir logs. One hundred twenty small-diameter interior Douglas-fir logs were grouped into three sweep categories. All logs were curve sawn, and the resulting 2x6-inch 16-foot lumber was dried in a commercial dry kiln, planed, and measured for bow, crook, twist, MOE, and grade.

Most of the lumber sawn from all three log groups was of high quality with small knots and little warp. A majority of this lumber graded Select Structural or #1 in the Western Wood Products Association Structural Joists and Planks category (Western Wood Prod. Assn. 1998). Although warp was recorded in every piece of study lumber, only one piece (moderate-sweep log group) had sufficient warp to be degraded from Select Structural or #1 to #2. Analyses of measurements taken shortly after drying and after 73 days of storage showed that mean bow was significantly greatest and that mean twist was significantly (marginally) least in lumber sawn from the high-sweep log group. Analyses also showed that MOE and the proportion of Select Structural lumber were significantly greatest in lumber sawn from the high-sweep log group.

These findings indicate that high-quality structural lumber can be produced through curve sawing small-diameter Douglas-fir logs. These findings also challenge traditional thinking that straight logs are superior to logs with sweep for the production of structural lumber.

BACKGROUND AND INTRODUCTION

More than 5 billion board feet of softwood lumber were produced in the Inland Northwest region during 1999, and the largest species contribution to this volume was Douglas-fir (*Pseudotsuga menziesii*) (approximately one third of the total) (Western Wood Prod. Assn. 2000). Even with this heavy use, the proportion of Douglas-fir sawtimber in forest stands has been increasing because of effective fire protection for the past 90 years and because of past selective logging of early-successional species such as ponderosa pine (Fiedler et al. 1999; Mutch et al. 1993). With implementation of ecological-restoration/fire-treatment prescriptions across many ownerships, it is expected that the volume of Douglas-fir sawtimber harvested within the region and manufactured into lumber will grow even higher. While prescriptions may involve removing some larger sawtimber, treatments will require removing increasing quantities of relatively small [6 to 12-inches (150 to 300 mm)d.b.h.] 60 to 120-year-old sawtimber (Fiedler et al. 1999). This sawtimber will likely be sawn on modern high-speed, curve-sawing sawmills (Wagner et al. 2000).

Research has shown that curve sawing can improve lumber recovery and sawing accuracy for small-diameter logs (Wang 1992). In that research, curve sawing improved lumber recovery by 16 to 4% for logs with average top diameters of 4.4 to 7.1 inches (110 to 180 mm), respectively. Curve sawing also resulted in more uniform lumber sizes. However, little has been reported on warp, strength/stiffness, or grade of lumber curve-sawn from this type of sawtimber. The purpose of this study was to evaluate the quality of structural lumber curve sawn from small-diameter, Douglas-fir logs that contained varying amounts of sweep.

METHODS

One hundred twenty 7-inch (178 mm), 16-foot (4.88 m) interior Douglas-fir butt logs were selected from the log yard of a cooperating sawmill in northeastern Washington. Logs were from trees approximately 75-years old harvested from northeastern Washington and/or northern Idaho forests. Growth of the trees was quite slow [more than 20 growth ring per inch (25 mm)] for the last 25 to 30 years.

Selected logs were placed into three groups of sweep; 1 inch (25 mm) or less sweep (straight), 1.5 to 2.5 inches (38 to 64 mm) sweep (moderate sweep), and 3 inches (76 mm) and greater sweep (high sweep). Sweep was determined by stretching a line across the concave face of each log from the log edge at one end to the log edge at the other end and measuring greatest distance from the straight line to the log surface. All logs were sound and free of defects except for knots.

Study logs were then curve sawn using the same headrig and sawing pattern at the cooperating sawmill. The sawing pattern produced a centered 2x6-inch [finished size 1.5 by 5.5 inches (38 by 140 mm)] piece and two 2x4-inch [finished size 1.5 by 3.5 inches (38 by 89 mm)] side pieces of lumber from each log. The headrig contained profiling chipper canters on the top, bottom, and sides of the logs, vertical-arbor gang circular saws, and a curve sawing feed. Logs were fed through the headrig in a curve (sweep up) so that the lumber was sawn with bow (bent flatwise).

Only the centered 2x6-inch pieces 16-feet (4.88 m) long were evaluated in this study. The 2x6-inch centered pieces were used because they had the highest propensity for warp according to the cooperating-sawmill personnel, and only 16-foot long pieces were used because they could be more easily compared for warp, strength/stiffness, and grade than could lumber of different lengths. Thirty three, 27, and 21

Published in *Small Diameter Timber: Resource Management, Manufacturing, and Markets* proceedings from conference held February 25-27, 2002 in Spokane, Washington. Compiled and edited by D.M. Baumgartner, L.R. Johnson, and E.J. DePuit. Washington State University Cooperative Extension. (Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912. MISC0509. 268 pp.

pieces of 2x6-inch 16-foot lumber were produced from 40 logs in each of the straight, moderate-sweep, and high-sweep log groups, respectively. Some lumber in each group was discarded because of excessive wane. Excessive wane would have made it difficult to measure warp and compare warp between groups. Additionally, some lumber from the moderate-sweep and high-sweep log groups was not used because a few logs from each group were misaligned (sweep to the side rather than up) as they were processed by the curve-sawing headrig. Resulting lumber was discarded because it was not sawn along the sweep of the log and thus contained excessive wane (especially near the ends) and excessive cross grain. Study lumber from each log group was randomly stacked and dried in the same charge of a dry kiln at the cooperating sawmill. Following drying, the study lumber was planed and transported to the University of Idaho Wood Laboratory.

Each piece of lumber was then measured for average moisture content (MC) with a Wagner l601-3 moisture meter. Measurements were taken at three positions along the length of each piece of lumber. Warp was measured with the use of a specially-designed jig in accordance with the Western Wood Products Association definitions of bow, crook, and twist (Western Wood Prod. Assn. 1998). Bow was measured by placing each piece on edge and measuring greatest horizontal distance from a straight line drawn from end to end. Crook was measured by placing each piece flatwise on the jig and measuring greatest horizontal distance from a straight line from end to end. Twist was measured by fixing one end of each piece against the jig (both corners tight against the jig), pressing the other end to the jig until one corner touched the jig, and measuring the distance that the other corner was raised above the jig.

Following initial measurements, the lumber was dead piled (tight stacked), wrapped, and stored indoors for 73 days. The lumber was then measured for moisture content, bow, crook, and twist, as described above. In addition, the lumber was measured for MOE using a Metriguard E-computer and was inspected by a Western Wood Products Association lumber inspector for Structural Joists and Planks grades and for visual override grades of Machine Stress Rated Lumber (Western Wood Prod. Assn. 1998).

RESULTS

Statistical analyses (2-way t tests) showed that mean log diameters were 6.83, 6.85, and 6.71 inches (175, 174, and 170 mm) for the straight, moderate-sweep, and high-sweep log groups, respectively. There were no significant differences (P>.05) in diameter between groups.

Initial mean moisture-content measurements were 12.97, 13.04, and 13.19% for lumber sawn from the straight, moderate-sweep, and high-sweep log groups, respectively. These mean moisture-content measurements were slightly lower than the target moisture-content often sought within the region to meet the grade specification of 19% moisture content for structural lumber (Western Wood Prod. Assn. 1998). Two-way t tests showed no significant differences (P>.05) in lumber moisture-content between groups. After 73 days of storage, lumber mean moisture contents were 12.00, 11.85, and 12.33% for lumber sawn from the straight, moderate-sweep, and high-sweep log groups, respectively. Again, two-way t tests showed no significant differences (P>.05) in lumber moisture content between groups. However, two-way t tests did show highly-significant (P<.001) moisture loss between initial and 73-day measurements.

Initial mean bow measurements were 0.34, 0.34, and 0.49 inches (8.5, 8.7, and 12.2 mm) for lumber from the straight, moderate-sweep, and high-sweep log groups, respectively (Fig. 1). Two-way t tests of initial warp measurements showed that mean bow was significantly greater (P<.01) in lumber sawn from the high-sweep log group than in lumber sawn from the other two log groups. After 73 days of storage, mean bow measurements were 0.25, 0.28, and 0.46 inches (6.4, 7,1, and 11.7 mm) for lumber from the straight, moderate-sweep, and high-sweep log groups, respectively (Fig. 2). Again, two-way t tests showed that mean bow was significantly greater (P<.01) in lumber from the high-sweep log group than in lumber from the other two log groups. These findings were not surprising because the lumber from logs with sweep are curve sawn in a bow. Apparently some of that bow was straightened during the drying process, but some remained. Additionally, two-way t tests showed a highly-significant (P<.001) decrease in mean bow between initial measurements and 73-day measurements. This finding was surprising because warp measurements usually increase with losses in moisture content. It should be noted that all lumber in this study contained

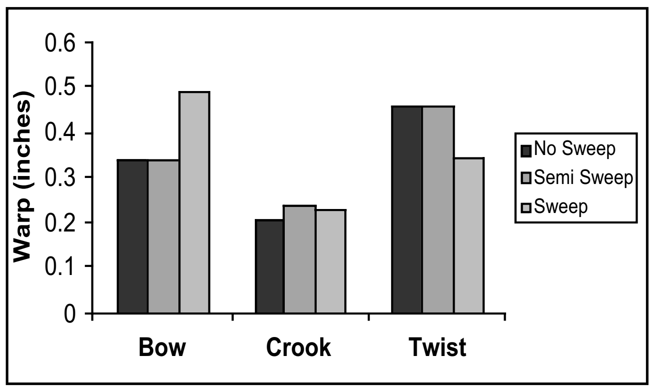

Figure 1.—Mean bow, crook, and twist measurements taken shortly after drying for lumber from the three log-sweep groups.

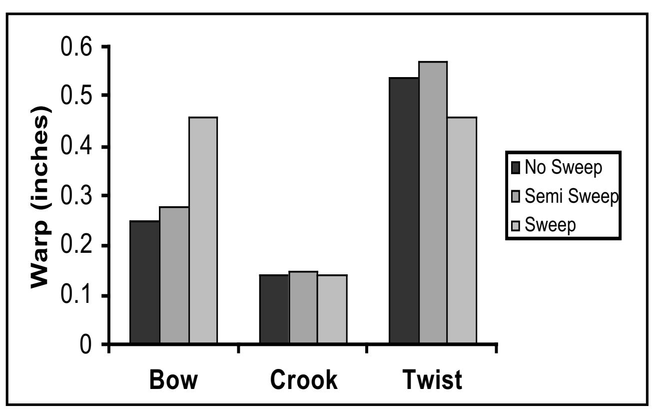

Figure 2.—Mean bow, crook, and twist measurements taken 73 days after the initial measurements for lumber from the three log-sweep groups.

very little bow. None of the pieces had sufficient bow (1-3/8 inches or 35 mm) to be degraded from Select Structural or #1 to #2 according to the Western Wood Products Association Grading Rules (Western Wood Prod. Assn. 1998).

Initial mean crook measurements were 0.21, 0.24, and 0.23 inches (5.4, 6.1, and 5.9 mm) for lumber from the straight, moderate-sweep, and high-sweep log groups, respectively (Fig. 1). Two-way t tests of initial warp measurements showed that mean crook in lumber did not differ significantly (P>.05) between log groups. After 73 days of storage, mean crook measurements were 0.14, 0.15, and 0.14 inches (3.4, 3.8, and 3.5 mm) for lumber from the straight, moderate sweep, and high-sweep log groups, respectively (Fig. 2). Again, two-way t tests showed that mean crook in lumber did not differ significantly (P>.05) between the log groups. Additionally two-way t tests showed a highly-significant (P<.001) decrease in mean crook between initial and 73-day measurements. As with mean bow, this decrease in mean crook was surprising because warp measurements usually increase with losses in moisture content. It should be noted that all lumber in this study contained very-little crook. None of the pieces had sufficient crook (11/16 inches or 17 mm) to be degraded from Select Structural or #1 to #2 according to the Western Wood Products Association Grading rules (Western Wood Prod. Assn. 1998).

Initial mean twist measurements were 0.46, 0.46 and 0.35 inches (11.6, 11.7, and 8.7 mm) for lumber from the straight, moderate-sweep, and high-sweep log groups, respectively (Fig. 1). Two-way t tests showed a marginally-significant (P<.075) lower mean twist in lumber sawn from the high-sweep log group than in lumber sawn from the other two log groups. This finding of lower twist in lumber sawn from the high-sweep log group substantiates an earlier finding by Taylor and Wagner (1996) in lumber straight-sawn from Douglas-fir logs. After 73 days of storage, mean twist measurements were 0.54, 0.57, and 0.46 inches (13.8, 14.4, and 11.6 mm) for lumber from the straight, moderate-sweep, and high-sweep log groups, respectively (Fig. 2). Again, two-way t tests showed marginally-significantly (P<.075) lower mean twist in lumber from the high-sweep log group than in lumber from the other two log groups. Additionally, two-way t tests showed a highly-significant (P<.001) increase in mean twist between initial measurements and 73-day measurements. It should be noted that all lumber in this study contained relatively little twist. Only one of the pieces had sufficient twist (1-1/8 inches or 29 mm) to be downgraded from Select Structural or #1 to #2 according to the Western Wood Products Association (WWPA) Grading Rules (Western Wood Prod. Assn. 1998).

Analyses showed that Modulus of Elasticity (MOE) was greatest in lumber from the high-sweep log group. Mean MOE values were 1.77, 1.84, and 2.00 million pounds per square inch (12,204, 12,687, 13,790 mega Pascals) for lumber from the straight, moderate-sweep, and high-sweep log groups, respectively. Two-way t tests of MOE values showed that mean MOE was significantly (P<.05) greater in lumber from the high-sweep log group than in lumber from the other two log groups. However, it should be noted that mean MOE values for lumber from all three log groups were relatively high. These mean MOE values exceeded the WWPA average MOE value for #1 Douglas-fir/larch framing lumber (Western Wood Prod. Assn. 1999). In fact, the mean MOE value for lumber from the high-sweep log group exceeded the WWPA average MOE value for Select Structural framing lumber. Thus, a high-proportion of this lumber would be suitable for the higher-value Machine Stress Rated (MSR) lumber grades.

Grades assigned to the lumber by the Western Wood Products Association lumber inspector were high in both the Structural Joists and Planks category and the visual-override MSR lumber category (Figs. 3 and 4). Knots were small compared to lumber sawn from larger trees, and as mentioned above warp (twist) was a grade factor in only one piece. Overall, 45 pieces (56%) graded Select Structural, 17 pieces (21%) graded #1, 16 pieces (20%) graded #2, and 3 pieces (4%) graded #3 in the Structural Joists and Planks category (Western Wood Prod. Assn. 1998). The high-sweep log group had a higher percentage (71%) of lumber that graded Select Structural than did the other two log groups. Additionally, 71 pieces (88%) from all log groups graded #1 (nearly equal percentages from each of the log groups), 3 pieces (4%) graded #2, 3 pieces (4%) graded #3, and 2 pieces (2%) graded #4 in the visual-override MSR lumber category. This means that if this lumber had been assigned an MSR value, only a few pieces would have been downgraded due to visual defects.

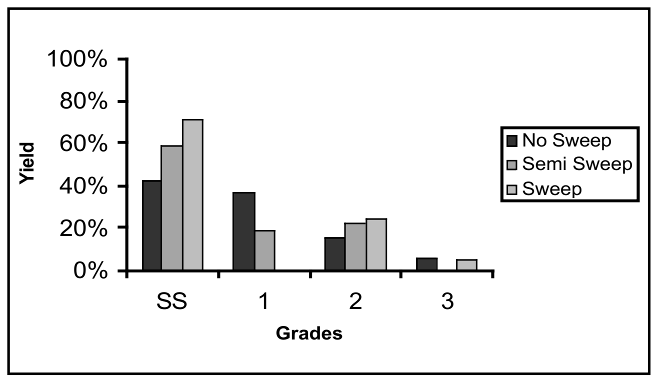

Figure 3.—Western Wood Products Association Structural Joists and Planks grades (6) for lumber from the three log-sweep groups.

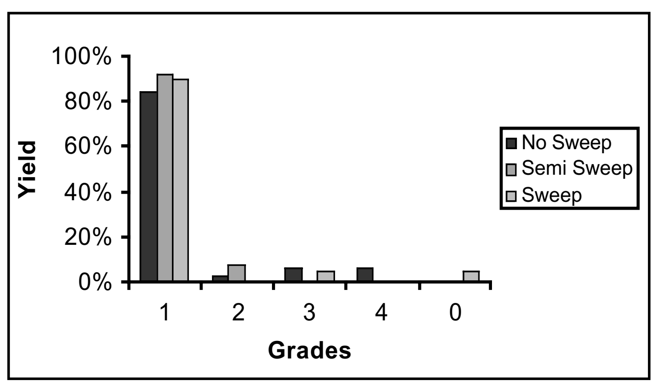

Figure 4.—Western Wood Products Association MSR visual-override grades (6) for lumber from the three log-sweep groups.

CONCLUSIONS

The 2x6 structural lumber produced by curve sawing small-diameter Douglas-fir butt logs in this study was of high quality (little warp, high MOE, and high grade). The logs used in this study were from small trees (approximately 9-inches d.b.h.) that were approximately 75 years old and typical of those found in high-density stands that have evolved throughout much of western North America due to past forest management practices and fire suppression. Results of this study indicate that high-quality (high-value) structural lumber could be produced from small-diameter Douglas-fir trees that may be harvested over millions of acres of forests under various ecosystem-restoration/fire treatment prescriptions.

Additionally, analyses of warp measurement values showed that mean bow was significantly greatest in lumber produced from the high-sweep log group. This was expected because curve sawn lumber from high-sweep logs are sawn in a bow. Apparently some of that bow was straightened during the drying process, but some remained. However, mean twist was significantly (marginally) least in lumber sawn from the high-sweep log group. The reason for this is not clear. It is speculated that since spiral grain is a leading cause of twist in lumber, trees with high sweep may have a lesser amount of spiral grain. Also, mean MOE was greatest and the occurrence of the Select Structural grade was highest in lumber produced from the high-sweep log group. These findings challenge tradithought that straight logs are superior to logs with sweep for the production of structural lumber.

REFERENCES

Fiedler, C.E., C.E. Keegan, D.P. Wichman, and S.F. Arno. 1999. Product and economic implications of ecological restoration. Forest Products J. 49(2) 19-23.

Mutch, R.W., S.F. Arno, J.K. Brown, C.E. Carlson, R.D. Ottmar, and J.L. Peterson. 1993. Forest health in the Blue Mountains: a management strategy for fire-adapted ecosystems. USDA Forest Service General Technical Report PNW-GTR-310.

Taylor, F.W. and F.G. Wagner. 1996. Impact of log sweep on warp in Douglas-fir structural lumber. Forest Prod. J. 46(9):53-56.

Wagner, F.G., C.E. Fiedler, and C.E. Keegan. 2000. Processing value of small-diameter sawtimber at conventional stud sawmills and modern high-speed, small-log sawmills in the western U.S.—a comparison. Western J. of Applied Forestry 15(4):208-212.

Wang, S.J., B.D. Munro, D.R. Giles, and D.M. Wright. 1992. Curve sawing performance evaluation. Forest Prod. J. 42(1):15-20.

Western Wood Products Association. 1998. Western Lumber Grading Rules 98. Western Wood Products Association. Portland, OR. 248 pp. plus supplements.

Western Wood Products Association. 1999. Western Lumber Product Use Manual. Western Wood Products Association. Portland, OR. 24 pp.

Western Wood Products Association. 2000. 1999 statistical yearbook of the western lumber industry. Western Wood Products Association. Portland, OR. 34 pp.

Authors

Francis G. Wagner, Professor
Forest Products Department
University of Idaho
Moscow, ID 83844-1132
208-885-6700
fwagner@uidaho.edu

Thomas M. Gorman
Professor and Head
Forest Products Department
University of Idaho
Moscow, ID 83844-1132
208-885-7402
tgorman@uidaho.edu

Keith L. Pratt
Truss Designer/Management Trainee
BMC West Corporation-Carson Valley
2587 Business Pkwy.
Minden, NV 89423

Charles E. Keegan, Associate Director
Bureau of Business and Economic Research
University of Montana
Missoula, MT 59812
406-243-5113
charles.keegan@business.emt.edu

This research was partially funded by the USDA CSREES Inland-Northwest Forest Products Research Consortium-Special grant #99-34158-7883 and Vaagen Brothers Lumber Company, Colville, WA.