The effect of curve sawing two-sided cants from small-diameter hardwood sawlogs on lumber and pallet part yields

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Abstract

Curve sawing is a primary log breakdown process that incorporates gang-saw technology to allow two-sided cants from logs with sweep to be cut parallel to the log surface or log axis. Since curve-sawn logs with sweep are cut along the grain, the potential for producing high quality straight-grain lumber and cants increases, and strength, stiffness, and dimensional stability are maximized. Presently, curve sawing methods are widely incorporated in high production softwood lumber manufacturing facilities. However, with a few exceptions, the practice of curve sawing is virtually nonexistent in hardwood sawmills. A previous study indicated that approximately one-third of hardwood sawlogs contain measurable sweep. The purpose of this study was to investigate the impact of sawing pattern (straight vs. curve sawing) on lumber, cant, and pallet part yield from small-diameter hardwood logs with varying degrees of sweep. The results of this study indicate that cant and pallet part yields are not affected by sweep since cants are cut from the center of a log. Although curve-sawn pallet cants did not straighten out completely when stacked, they did not cause handling problems during the pallet part manufacturing process. The yield of lumber from the outside of curved logs increases significantly when curve sawn. The results indicate that lumber yield can be as much as 10 to 12 percent higher when curve sawing hardwood logs with an average sweep of 3.3 inches and greater (12-ft basis). Since approximately one-third of hardwood logs are not considered straight, significant lumber yield improvements can occur when curve sawing lumber and cants from these logs.

Of the total solid wood used to manufacture wood pallets, approximately 67 percent (4.41 billion board feet [BF]) is mixed hardwood species in the form of lumber, cants, and small-diameter logs. Approximately 40 percent of all hardwood material processed in the United States is channeled into the pallet manufacturing industry (Bejune et al. 2002).

Integrated pallet mills will purchase small logs and saw them into pallet cants or lumber using small-log processing systems. Pallet manufacturers without log sawing capability will purchase cants from hardwood grade sawmills or sawmills sawing small lower grade logs. Pallet cants sawn from small-diameter logs will often contain higher quality material than cants sawn from the center of the larger diameter grade logs.

While it is important that pallet manufacturers strive to maximize yield and quality of cants and lumber, the occurrence of a log defect known as sweep limits traditional saw milling efficiency. Sweep is traditionally characterized as uniform curvature along the entire log length. The measure for sweep is the maximum deviation of the curved surface of a log. Hardwood sawmills traditionally straight saw their logs, allowing for taper only when the sawlines are parallel to the log central axis and/or straight surface. When straight sawing lumber, yield decreases as the level of sweep increases in a log (Ronnqvist et al. 2000). Furthermore, processing curved logs

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Figure 1. — Photograph of Esterer sash gang saw. This saw was used to both curve saw and straight saw the study logs from each sweep group.

results in shorter boards and cants, which may limit the yield of pallet parts obtained from them.

To the extent that sweep is present in logs, the effect it has on lumber recovery is dependent on a combination of three factors: the level of the curvature, log diameter, and log length. These factors are used in a log grading scale deduction calculation, called sweep deduction, which estimates the percentage lumber yield loss that would occur when straight sawing a log with sweep (Rast et al. 1973). According to Hamner et al. (200_), the majority of hardwood sawlogs are relatively straight. However, 32 percent have measurable sweep of 1 inch or more. For logs that have sweep, the level of estimated sweep deductions when straight sawing is inversely related to diameter size (Hamner et al. 200_). This indicates the possibility of substantial yield improvements for all primary hardwood manufacturers when sawing small-diameter hardwood logs.

Curve sawing is a sawing process that incorporates gang-saw technology to allow logs or two-sided cants with sweep to be cut along the natural line of curvature. There are two basic curve sawing techniques. One method manipulates a curved cant through stationary saws, while the other method uses articulating saws that follow the contour of the log (Nelson 2001). It has been shown that curve sawing softwood logs with sweep increases lumber recovery and lumber quality (Wang et al. 1992). Since curve-sawn logs are cut along the grain, the potential for producing higher quality lumber increases (Wagner et al. 2002). Curve-sawn lumber from sweepy softwood logs are wider and slightly longer than straight-sawn lumber from curved logs (Petree 1998). Although this practice has been used since the early 1900s, it has only recently been incorporated into high-production softwood lumber manufacturing facilities. Wang et al. (1992) showed that curve sawing can improve lumber recovery by as much as 16 percent from small-diameter softwood logs with sweep.

Research objectives

The purpose of this study was to compare lumber, cant, and pallet part yield from both straight sawing and curve sawing two-sided, 6- and 8-inch-thick cants from small-diameter hardwood sawlogs with sweep.

Research methods

Lumber yield and pallet part yield studies were conducted at a local sawmill equipped with an Esterer sash gang resaw (sawkerf 0.130 to 0.135 in) (**Fig. 1**), and a local pallet mill, respectively. For this study, a total of 134 small-diameter hardwood logs (1,250 ft^3: Smalian) were utilized. These logs were relatively low grade and would be considered typical for pallet part production. Sweep was measured first by locating the side of the log from which the greatest deviation of the curved surface could be observed, and then tightening a string over this area from one end of the log to the other. Butt swell, lumps, and other surface anomalies not associated with deviation in the stem were not included in the measure.

Using a ruler, sweep was recorded as the maximum distance (in) measured perpendicular from the string to the curved surface of the log (Hamner et al. 200_). The logs in this study ranged in length from 8 to 16 feet. Most logs in the study exhibited uniform curvature along log length. The curvature for some logs was limited to less than log length and would, therefore, represent a higher level of sweep for the same measured deformation.

To effectively compare the differences in the degree of curvature between logs of varying lengths, it was necessary to normalize the measure for sweep according to a standard length basis (Hamner et al. 200_). In each sweep category and sawing process group, logs ranged in length from 8 to 16 feet. Curve, shape, and sweep were not differentiated. All were assumed the same and measured over the entire length of the log. The curvatures of a few logs in the study at some sample locations were not uniformly curved along the entire log length, which is the traditional characteristic of sweep. Therefore, the normalized sweep represents an approximate curvature value. Equation [**1**] is the relationship between the length of a chord of a circle and the maximum distance between the circular arc and the chord (Simpson and Shelly 2000). A 12-foot log length basis was used because it approximates the average length of hardwood logs in this study.

$$S_2 = S_1(12/L)^2 \qquad [\mathbf{1}]$$

where S_1 = maximum measured log sweep (in); S_2 = sweep normalized to 12-foot basis; L = measured log length (ft).

The study logs were categorized into three groups based on the severity of sweep present in them. Equation [**2**] shows the calculation for percent sweep scale deduction that is used as part of the standard USDA Forest Service grading procedure for hardwood logs (Rast et al. 1973). This equation was used to quantify the percent sweep scale deduction for all logs and categorize them into three groups based on the magnitude of percent sweep scale deduction.

$$\text{Percent sweep scale deduction} = \frac{(S - L/8)}{\text{SED}} \qquad [\mathbf{2}]$$

where S = sweep (in); L = length (ft); SED = small-end diameter (inside bark).

All logs were color coded according to the percentage of sweep scale deduction present in them: 0 to 15 percent (green), 16 to 30 percent (red), greater than 30 percent (black). Logs were color coded by spray painting both ends of each log. **Figures 2**, **3**, and **4** show the logs used in this study from each percentage sweep scale deduction category. Painting the ends of the logs permitted the matching and tracking of lumber, cants, and pallet parts sawn from logs in each sweep scale deduction group.

Figure 2. — Logs having between 0 and 15 percent sweep scale deduction.

Figure 3. — Logs having between 16 and 30 percent sweep scale deduction.

Figure 4. — Logs having greater than 30 percent sweep scale deduction.

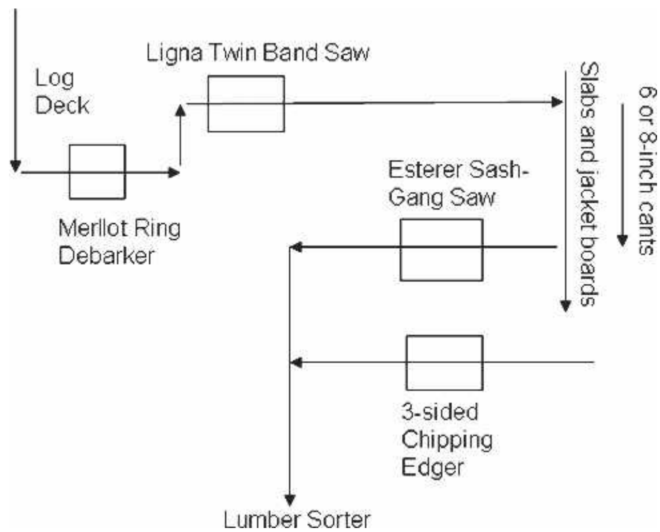

Figure 5. — Schematic diagram of sawing sequence.

Within each sweep scale deduction category, the logs were divided randomly into two groups: one group for straight sawing and one group for curve sawing. Grouped for straight sawing were 39, 20, and 11 logs representing the low, intermediate, and severe sweep categories, respectively. The logs destined for curve sawing included 38, 16, and 10 logs representing the low, intermediate, and severe sweep categories, respectively. Approximately 360 ft^3 of 0 to 15 percent sweep scale deduction logs, 170 ft^3 of 16 to 30 percent sweep scale deduction logs, and 90 ft^3 of greater than 30 percent sweep scale deduction logs were in each sawing process group. Small-end diameter, length, and volume (Smalian) were measured and recorded for each color-coded sawing method group. All material processed from both the curve- and straight-sawn logs was kept separate throughout this study.

The sawing process was conducted in two separate phases: straight sawing first, and curve sawing second. **Figure 5** is a schematic diagram showing the log sawing sequence of the sawmill used during the lumber yield study phase of the project. The logs were first debarked by a Mellot ring debarker and then conveyed to a Ligna twin band headrig (sawkerf 0.140 in). The twin band headrig makes a two-sided cant by removing slabs and unedged jacket boards until reaching a 6- or 8-inch-thick cant, depending on log diameter. The slabs flow straight to a three-sided chipping edger. All logs with sweep were cut either sweep side up or sweep side down on the Ligna twin band such that the remaining cant could lay flat. The 6- and 8-inch two-sided cants were then sent to the Esterer sash gang saw. The sash gang saw was used to both straight saw and curve saw the two-sided cants. When curve sawing the cants, the sash gang saw operator would manually manipulate the log through the saw and follow the log contour. The bandsaw blades on the sash gang were set to cut unedged boards 1.375 inches thick, while leaving a full 4-inch-wide gap in the middle of the arbor to produce a 4- by 6-inch or 4- by 8-inch cant for pallet part production. Jacket boards cut on the Ligna twin band were sawn 1.125 inches thick. The three-sided chipping edger would recover boards from slabs generated at the Ligna twin band as 1.125- or 1.75-inch-thick by 3.75, 5.75, 7.75, 9.75, or 11.75 inches in width. The sawing pattern is shown schematically in **Figure 6**. The curve-sawing pattern is actually a combination of straight sawing at the head saw and curve sawing of the cant at the sash gang saw. Round edge boards from the sash gang were not edged or trimmed at the mill. They were edged and trimmed visually when the lumber was tallied. All visual edging and trimming were based on the requirements of well-manufactured 1 Common lumber grade appearance according to the Rules for Measurement and Inspection of Hardwood and Cypress Lumber (NHLA 2003).

After the sawmill operations were completed, all lumber and pallet cants were sorted and tallied according to each sweep scale deduction category. All pallet cants produced from both sawmill processes were sent to the pallet mill for further processing into pallet deckboards of identical dimensions: 0.5 by 3.1875 by 40 inches. At the pallet mill, cants were cut to 40-inch lengths using a Pendu circle saw. The shorts were then ripped into 0.5-inch-thick deckboards using a Pendu double arbor gang ripsaw (0.055-inch kerf). Pallet parts were sorted and tallied by sawing process and sweep scale deduction category. Cants and trim less than 40 inches in length were considered salvageable if their length was ≥ 24 inches. Salvage cants also were sorted and tallied by sawing process and sweep deduction category, and included in the analysis as pallet parts. Lumber and pallet part yield were determined by comparing their respective tallies in BF to the total log volume (Smalian) in BF as shown in Equation [**3**]:

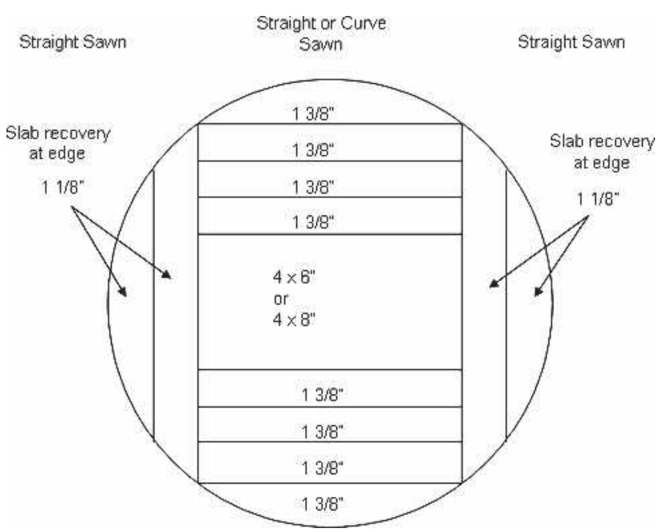

Figure 6. — Diagram of sawing pattern used to sawlogs for both straight and curve sawing log groups.

$$\text{Yield} = \frac{L \text{ or } P}{V_S \times 12} \qquad [\mathbf{3}]$$

where: L = total lumber tally (lumber + pallet cants) (BF); P = pallet part tally (BF); V_S = volume Smalian (ft^3).

Also calculated were the lumber recovery factors (LRF), and overrun/underrun (based on the International 1/4 log scale). Hypothesis testing using analysis of variance (ANOVA; $\alpha = 0.05$) was conducted by comparing mean observations for each treatment effect: sawmill process (curve vs. straight sawing) and sweep deduction category.

Results and discussion

Table 1 contains a summary of the characteristics of the logs used in this study. Hypothesis testing using analysis of variance (ANOVA; $\alpha = 0.05$) indicated there was no significant difference in the small-end diameters or lengths for the logs used in this study, either across sweep deduction categories or between sawing processes. Normalized sweep was an average of 1.6, 3.3, and 6.5 inches for logs in the 0 to 15 percent, 16 to 30 percent, and greater than 30 percent sweep scale deduction categories, respectively.

The effect of sawing technique on lumber yields

A summary of the yield distribution for all lumber processed by both curve sawing and straight sawing, and for each sweep deduction category is shown in **Table 2**. The LRF and percent overrun values from the curve sawing of logs are consistently greater than the values for the straight-sawn logs. Combined total yield for the curve-sawn logs resulted in an LRF = 7.49 and an overrun = 33 percent, while the combined total yield for straight-sawn logs was lower: LRF = 6.92, and an overrun of 24 percent.

Based on Equation [**3**], the total lumber yield was 4 percent higher when curve sawing than when straight sawing for all logs sampled in the study. For the 0 to 15 percent sweep deduction category, there was no difference in lumber yield resulting from sawing method (62% each). This is significant considering it has previously been shown that approximately two-thirds of hardwood logs are considered straight (sweep deductions ≤ 5%) (Hamner et al. 200_). For the present study, logs in the 0 to 15 percent sweep deduction category averaged only 5 percent sweep scale deduction. It is, therefore, unclear from the results what yield improvements would be realized

Table 1. — Summary of study log characteristics and the relationship between sawing method and log sweep category.

	Sweep scale deduction category							
	0% to 15%		16% to 30%		> 30%		Combined	
	Straight	Curve	Straight	Curve	Straight	Curve	Straight	Curve
No. of logs	39	38	20	16	11	10	70	64
Percent of total logs per sawing method	56	59	29	25	16	16	100	100
Average log SED (in)	9.7 (1.6)[a]	10.1 (1.6)	9.4 (1.8)	10.3 (2.1)	9.7 (2.1)	9.8 (0.9)	9.6 (1.8)	10.1 (1.7)
Average log length (ft)	13.6 (1.5)	12.7 (1.7)	13.7 (1.5)	12.9 (1.9)	13.4 (2.2)	12.9 (2.5)	13.6 (1.5)	12.8 (1.8)
Avg. actual sweep (in)	1.9 (0.9)		3.9 (0.4)		7.1 (2.6)		3.3 (2.3)	
Avg. normalized sweep (in)	1.6 (0.9)		3.3 (1.3)		6.5 (3.2)		2.8 (2.3)	
Avg. log scale sweep deduction (%)	5 (5)		23 (5)		56 (23)		18 (21)	
Log volume: Smalian (ft^3)	370	354	184	159	98	85	652	598
International 1/4 log scale (BF)	2,060	1,955	1,005	895	563	510	3,628	3,360

[a]Values in parentheses are standard deviations.

Table 2. — Summary of lumber yield distributions.

	Sweep scale deduction category							
	0% to 15%		16% to 30%		> 30%		Combined	
	Straight	Curve	Straight	Curve	Straight	Curve	Straight	Curve
Lumber tally (BF)	2,761	2,644	1,188	1,221	562	614	4,511	4,478
Average lumber length (ft)	9.2 (3.8)[a]	9.5 (4.0)	9.2 (3.6)	8.7 (3.8)	7.2 (3.8)	8.1 (3.4)	8.9 (3.8)	9.1 (3.9)
Average lumber length/ average log length (ft)	0.7	0.7	0.7	0.7	0.5	0.6	0.7	0.7
LRF	7.47	7.47	6.45	7.70	5.72	7.19	6.92	7.49
Overrun (%)	34	35	18	36	0	20	24	33
Lumber yield (%)	62	62	54	64	48	60	58	62

[a]Values in parentheses are standard deviations.

Table 3. — Summary of pallet part yield distributions.

	Sweep scale deduction category							
	0% to 15%		16% to 30%		> 30%		Combined	
	Straight	Curve	Straight	Curve	Straight	Curve	Straight	Curve
Number of pallet parts	1,650	1,515	799	668	295	355	2,744	2,538
BF of pallet parts	874	802	423	354	156	188	1,453	1,344
Percent yield pallet parts (log basis)	20	19	19	19	13	18	19	19

for logs with an average sweep deduction ranging from 5 to 15 percent. Since approximately 20 percent of hardwood logs have sweep scale deductions within this range, and another 10 percent have been shown to have sweep scale deductions of greater than 15 percent, it is expected that overall yield improvements would be substantial for the nearly one-third of hardwood logs that exhibit sweep scale deductions of greater than 5 percent. Results from the present curve sawing study support this likelihood because curve sawing the intermediate (16% to 30% sweep deduction category) and severely curved (greater than 30% sweep deduction category) logs resulted in 10 and 12 percent yield improvements, respectively.

The effect of sawing technique on pallet part yield

Table 3 is a summary of pallet part yields sawn from cants. Curve sawing does not significantly improve pallet part yields from cants with low or intermediate levels of sweep. For the greater than 30 percent sweep deduction category of logs, pallet part yield was 5 percent greater when curve sawing. This is likely due to the fact that curve-sawn pallet cants from logs with greater than 30 percent sweep scale deduction were nearly 1 foot longer than straight-sawn pallet cants. The proportion of logs in this category was small (16%), and the number of pallet parts processed from this group did not contribute significantly to total pallet part yields. The discovery that pallet part yields are similar regardless of the sawing method is not surprising since only one pallet cant, either 4 by 6 inches or 4 by 8 inches, was sawn from each log. With few exceptions, the length of the cant will correspond to the length of the log. Thus, unless curve sawing logs with excessive sweep, the pallet cant volume, and pallet part volume from curved logs is little affected as a result of sawing method. It is also important to note that the curve-sawn pallet cants did not straighten out completely when stacked and were harder to handle than the straight-sawn pallet cants.

The effect of sawing technique on lumber length

Table 2 also contains a summary of the average length of boards sawn and the average length of the logs from which they were sawn. There were no differences in average log lengths between sweep scale deduction categories or sawing process groups. The results from this study indicate there is no significant difference ($\alpha = 0.05$) in average lengths of curve-sawn and straight-sawn boards. This is not surprising since the curve-sawing pattern is a combination of curve sawing at the sash gang and straight sawing at the headsaw. However, as previously mentioned, for logs in the greater than 30 percent sweep deduction category, curve-sawn lumber was nearly 1 foot longer than straight-sawn lumber: 8.1 vs. 7.2 feet, respectively. It has previously been shown that logs with sweep deductions of greater than 30 percent make up only approximately 2 percent of hardwood sawlogs. Thus, for log and cant sawing patterns similar to those used in the study, one should not expect considerably longer lumber when curve sawing.

Summary and conclusions

Lumber yield

In this study, logs, or two-sided cants, from 134 small-diameter hardwood logs of varying sweep characteristics were either curve or straight sawn to determine and compare the effect of these sawing methods on lumber and pallet part yields. The results indicate that, compared to straight sawing, curve sawing 6- and 8-inch two-sided cants does not significantly improve lumber yield from small-diameter hardwood logs with average sweep scale deductions of approximately 5 percent and an average of 1.6 inches of sweep (12-foot log length basis). For hardwood logs with average sweep of 3.3 inches and greater (12-foot log length basis), and log scale deduction of over 15 percent, lumber yield can be 10 to 12 percent higher when curve sawing. Since approximately one-third of hardwood logs are not considered straight, i.e., having greater than 5 percent sweep scale deduction (Hamner et al. 200_), significant yield improvements can occur when curve sawing cants from these logs.

Pallet part yield

The results of this study reveal that, compared to straight sawing, curve sawing cants from logs has no effect on total pallet part yields. For severely curved logs with greater than 30 percent sweep scale deduction, or an average 6.5 inches or more sweep, pallet part yields from curve sawing are somewhat greater. However, these logs are a small percent of the log population and should be cut to length before sawing.

Lumber length

The results of this study indicate that, compared to straight sawing, there is no significant change in average lumber length due to curve sawing cants from logs with less than 30 percent sweep scale deduction, or average sweep ranging from 0 to 3.3 inches (12-ft basis). For severely curved logs, curve-sawn lumber will be an average of 1 foot longer than straight-sawn lumber.

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