The frequency and level of sweep in mixed hardwood saw logs in the eastern United States

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Abstract

Hardwood sawmills traditionally saw logs in a manner that either orients sawlines parallel to the log central axis (straight sawing) or the log surface (allowing for taper). Sweep is characterized as uniform curvature along the entire length of a log. For logs with sweep, lumber yield losses from straight and taper sawing increase with increasing levels of sweep. Curve sawing logs with sweep will increase yields by allowing logs with sweep to be sawn along their natural line of curvature. To better understand the potential for the utilization of curve sawing technology in hardwood sawmills of the eastern United States, it was necessary to determine the frequency and degree of sweep that occurs in hardwood sawlogs. In this study, 1,700 random hardwood logs from 17 sawmills located across eight eastern states were measured, analyzed, and classified for level of sweep based on the log scale deduction percentage attributed to sweep. Whereas the majority of eastern hardwood logs are considered straight, our results show that nearly one third of hardwood sawmill inventories have enough curvature to incur sweep scale deductions of 5 percent or more. For these logs, sweep scale deduction percentages increase as small-end diameter decreases and as length increases. Of the primary species sampled in this study, oak logs exhibited the highest average sweep scale deduction—5.9 percent.

The eastern region of the United States contains the vast majority of the nation's hardwood timber resource and is responsible for 97 percent of the U.S. annual production of hardwood lumber (The Timber Tax 2002). In recent years the softwood lumber industry has widely adopted curve sawing technology to increase lumber yield from sawlogs that exhibit sweep (Woodward 2003, Corino et al. 2006). Sweep is traditionally characterized as uniform curvature along the entire log length. At present, curve sawing is generally not utilized in the hardwood lumber industry. Hardwood sawmills traditionally straight saw logs allowing only for taper with sawlines parallel to the log central axis and/or straight surface. However, when straight sawing, yield loss increases as the level of sweep increases in a log (Ronnqvist et al. 2000).

Curve sawing generally incorporates gang sawing two sided cants with sweep (curvature) to be cut along the natural line of curvature (Petree 1998). 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 a log (Nelson 2001). This technology has the potential to increase both the yield and quality of lumber from hardwood logs exhibiting various levels of sweep.

A recent study evaluated the effectiveness of curve sawing vs. straight sawing two-sided cants from small diameter hardwood logs (Hamner et al. 2006). In this study, the lumber yield from curved logs increased significantly when curve sawn. The results indicate that, based on a 12-foot log length scale, hardwood logs with average sweep greater than 1.6 inches can produce lumber yields as much as 12 percent higher when curve sawing.

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Previous studies have evaluated the curve sawing of softwood sawlogs (Wang et al. 1992, Wagner et al. 2002). The research concluded that, when compared to straight sawing, curve sawing logs with sweep increases the value of lumber sawn from curved logs in terms of both volume recovery and lumber quality. Since curve sawn boards are cut along the grain, the potential for producing higher quality lumber increases by reducing slope of grain. Straight grain lumber has less of a tendency to warp than does lumber with sloped grain (Petree 1998). Also, curve sawn boards from sweepy softwood logs are slightly wider and longer than straight sawn lumber from curved logs.

Log diameter affects lumber yield from logs that have sweep. The impact of curve sawing on yield is greater for smaller diameter logs. Research by Wang et al. (1992) showed that when curve sawing 16-foot logs with similar sweep characteristics (ranging from 1.01 to 1.60 inches), yield improved by 4 to 16 percent as top end diameters declined from 8 inches to less than 5 inches, respectively. Wagner et al. (2002) established three categories of sweep (for 16-foot logs) as follows: logs with ≤1-inch sweep are straight, logs with 1.5 to 2.5 inches have moderate sweep, and logs with ≥3 inches have high sweep. For hardwood logs, it will be helpful to categorize the level of sweep to determine cost-effectiveness criteria for curve sawing applications.

Figure 1. — Technique for measuring sweep.

Research objective

The relevance of the sweep defect in hardwood sawlogs is its potential to reduce lumber yield when straight sawing. The objective of this research was to evaluate the frequency and level of sweep in mixed hardwood sawlogs in the eastern United States for the purpose of better understanding the potential for utilizing curve sawing technology in hardwood sawmills.

Research methodology

Logs from 17 hardwood sawmills spanning eight states in the mideastern United States region of hardwood timber growth were sampled during this study. Only mills that did not reject logs based on sweep limitations were selected. The mills were located as follows: three in Virginia, four in North Carolina, one in West Virginia, one in Ohio, two in Kentucky, one in Tennessee, three in Pennsylvania, and two in New York. For this study, a total of 100 logs per mill (1,700 total) were selected at random, and measured and analyzed for sweep characteristics. Logs were selected as they arrived at a mill and before they could be sorted into species or size classes.

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, bumps, and other surface anomalies not associated with deviation in the stem were not included in the measure. Shown in **Figure 1**, sweep was recorded as the maximum distance (inches) measured perpendicular from the string to the curved surface of the log. Curve, shape, and sweep were not differentiated. All were assumed the same and measured over the entire length of a sample log. A few logs sampled in this study at some locations were not uniformly curved along the entire log length. Therefore, sweep was recorded as the maximum amount of curved deviation present in either a portion of a log or across the entire curved log length. Log length in feet, small-end diameter (SED) inside bark in inches, and tree species also were measured and recorded.

The sample logs used in this study ranged in length from 8 to 16 feet. Thus, to effectively compare differences in the degree of curvature between logs of varying lengths, it was necessary to normalize the measure for sweep using a standard log length basis of 12 feet (Eq. [**1**]). A 12-foot log length basis was used because it approximates the average length of hardwood logs in this study. Therefore, the normalized sweep calculation 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).

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

where:

S_1 = maximum measured log sweep (inches)

S_2 = sweep normalized to 12-foot basis.

L = measured log length (feet)

The relevance of the sweep defect in hardwood sawlogs is the potential for sweep to reduce lumber yield when straight sawing. The effect of log sweep on lumber yield depends on log small-end diameter, taper, and length. Rules for grading hardwood factory-lumber logs utilize a scale deduction to estimate lumber yield loss due to sweep (Rast et al. 1973). This scale deduction, known as sweep deduction, incorporates the degree of sweep, small-end diameter, estimated taper, and log length, to estimate the percentage of lumber yield that is lost when straight sawing logs with sweep. Because taper can mask the effect that sweep has on yield loss, it must be subtracted from "measured" sweep to determine what is often referred to as "absolute" sweep. In this study, large end diameters were not measured.

Table 1. — Length, diameter, and sweep characteristics for all 1700 hardwood study logs sampled based on log scale sweep deduction categories.

Log scale sweep deduction category	Logs		Length		Diameter		Sweep (12 ft basis)		Log scale sweep deduction	
	(No.)	(%)	Average	SD	Average	SD	Average	SD	Average	SD
			(ft)		(in)				(%)	
Straight[a]	1166	68.8	12.5	2.8	14.8	3.4	0.7	0.9	0.5	1.2
5 to 10 percent	216	12.8	11.6	2.8	15.2	3.5	3.0	1.0	7.0	1.4
10 to 15 percent	147	8.7	11.6	2.8	14.5	2.8	3.9	1.6	12.3	1.5
15 to 30 percent	136	8.0	11.3	2.8	14.2	3.7	5.5	2.4	20.5	4.0
>30%	29	1.7	12.0	2.4	12.9	3.1	7.4	4.0	38.9	9.2
All logs	1694	100.0	12.2	2.8	14.7	3.4	1.7	2.2	4.6	7.9

[a]Straight logs are defined as those logs having less than 5 percent sweep scale deduction.

For each study sample log, absolute sweep, small-end diameter, and log length were used to determine sweep log scale deductions. As is common in the hardwood industry, taper was calculated based on the International 1/4 inch Log Rule and Grosenbaugh's rules which both assume 1/2 inch of taper per 4 feet of log length (Grosenbaugh 1952). The calculation for percentage sweep deduction is shown in Equation [**2**] (Rast et al.).

$$\text{Percent sweep deduction} = \frac{(S - T)}{D} \times 100 \qquad [\mathbf{2}]$$

where:

S = measured sweep (inches)

T = Taper (inches) = length/8

D = small end d.i.b. (inches)

Percentage sweep log scale deduction was utilized in this study to support the evaluation of the degree and frequency of sweep in hardwood logs by categorizing, evaluating, and comparing the potential effects of sweep on lumber recovery in a typical straight sawing hardwood sawmill environment.

To analyze the distribution of sweep characteristics in this study, the logs were assigned to one of five sweep deduction categories based on Equation [**2**]. The first three categories range from 0 to 15 percent in 5 percent increments, while the remaining two categories are 15 to 30 percent and greater than 30 percent, respectively. The first three categories were divided into 5 percent increments to better characterize what was observed to be a large percentage of logs that had sweep deductions of 15 percent or less. The number and percentage of logs were recorded for each sweep category. Average and SD of length, diameter, and normalized sweep were also determined for each sweep category. Also, because a large percentage of the logs were observed as having little or no sweep, it was necessary to exclude these logs from additional analyses to better interpret the characteristics of sweep where it does occur. Thus, only those logs with 5 percent or more log scale deduction were further analyzed.

To determine the effect of log diameter on sweep log scale deductions, log diameters were divided into two classifications: small-diameter logs (SED $\leq$ 12 inches) and large-diameter logs (SED > 12 inches). To determine the effect of log length on sweep, log lengths were again separated in two length categories: short (<12 feet) and long ($\geq$12 feet). Logs were also sorted and analyzed by species. Hypothesis testing using analysis of variance (ANOVA; $\alpha = 0.05$) was conducted to determine any effects of log SED, log length, and log species, on normalized sweep and sweep deduction. A separation of means test (Tukey HSD) was used to test for significance between multiple independent samples.

Research results

Occurrence of sweep in hardwood logs

A summary of the physical characteristics for all 1,700 logs sampled in this study is presented in **Table 1**. From **Table 1** it is evident that the vast majority of hardwood logs have little or no discernable sweep. Of the 1,700 logs, sampled 69 percent (1166 logs) were determined to have an average of only 0.5 percent calculated sweep deduction. On a 12-foot log length basis, this is less than 1 inch of sweep (an average of 0.7-inches). These logs are therefore considered straight and no significant yield improvement would be expected from curve sawing.

Thirty-one percent of the logs (528) exhibited sweep scale deductions equal to or greater than 5 percent. The average sweep scale deduction for these curved logs was 13 percent. The average normalized sweep (12-foot log basis) for these same logs varied from 3.0 inches for the logs in the lowest sweep category to 7.4 inches for logs in the highest category.

Relationship between log length, small-end D.I.B., and sweep frequency and scale deductions

In **Table 1**, the average length and small-end diameter distribution of logs are presented for the five sweep deduction categories. There were no significant differences in average log length between the different sweep classes. Differences in average log diameter, however, were significant between sweep classes (p-value = 0.002577). Excluding straight logs, average log diameters for logs in the greater than 30 percent sweep deduction category were an average of 2.3 inches less than for logs in the 5 to 10 percent scale deduction category. **Figure 2** is a plot of average small-end diameters vs. normalized sweep for each sweep deduction category. Logs that exhibit greater normalized sweep tend to have smaller average small-end diameters.

For the purpose of further comparison and analysis, logs were grouped into two diameter and length classes. The relationship between log size (length and diameter) and estimated scale deduction is shown in **Table 2**. For the 528 logs not considered straight, the average normalized sweep for the two diameter classifications were similar: 4.2 inches for the large-diameter group vs. 3.9 inches for the small-diameter group. However, the average sweep deduction was nearly 4 percent

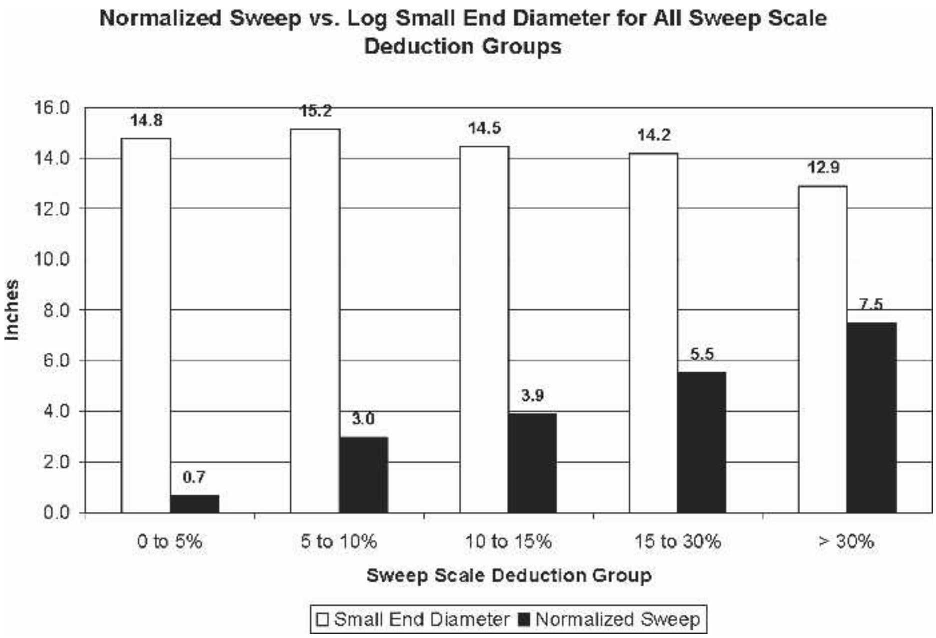

Figure 2. — Plot of average log small-end diameters vs. normalized sweep for each.

Table 2. — Relationship between log length, log diameter, and normalized sweep in hardwood logs with measurable sweep.[a]

Log size classification	Logs with sweep (No.)	Logs with sweep (%)	Length Avg.	Length SD	Diameter Average	Diameter SD	Sweep (12 ft basis) Avg.	Sweep (12 ft basis) SD	Sweep deduction Avg.	Sweep deduction SD
			----(ft)----		---------------(in)-------------				-----(%)-----	
Diameter class										
Small	145	27.4	11.6	2.7	11.1	1.1	3.9	2.2	16.4	10.8
Large	383	72.5	11.5	2.8	15.9	3.0	4.2	2.3	12.7	7.6
Length class										
Short	264	50.0	9.2	1.1	14.3	3.2	n/a	n/a	13.1	7.9
Long	264	50.0	13.9	1.8	14.9	3.6	n/a	n/a	14.3	9.5

[a]In this study, logs with measurable sweep are those 32 percent of logs with enough curvature (sweep) to result in a 5 percent or greater log scale deduction.

Table 3. — Percentage of straight logs and average small-end diameter, length, sweep, and sweep scale deduction by species group.

Species	Distribution of all study logs	Straight logs	Avg. smallend diameter	Avg. length	Avg. sweep (12 ft basis)	Avg. sweep deduction
	----------(%)----------		(in)	(ft)	(in)	(%)
Other	12.4	59.9	14.7	12.6	1.9	5
Maple	21.8	71.2	14.0	11.3	1.6	3.9
Yellow-poplar	23.7	68.6	14.9	13.0	1.7	5.2
Cherry	13.3	62.3	15.2	12.2	2.0	5.4
Oaks	28.9	60.3	15.1	11.2	2.3	5.9

more for the small-diameter class of logs than for the large-diameter class: 16.4 percent vs. 12.7 percent, respectively. The log scale deduction is greater for small-diameter logs with measurable sweep.

Log length had little impact on the percentage log scale deduction for the 528 study logs with measurable sweep. The average length for logs in the short group was 9.2 feet, compared to 13.9 feet for the long group. The average calculated sweep deductions were similar for both groups: 13.1 percent for the short logs and 14.3 percent for long logs. Although average actual sweep was 0.8 inches more for the group of longer logs, normalized sweep results for log length cannot be evaluated since the log length treatment variable itself was normalized to 12 feet. Scale deductions and sweep were not statistically different based on log length (p-value = 0.0909).

The influence of log species on sweep frequency and scale deduction

Table 3 shows log sweep characteristics as a function of log species. Most of the 1700 logs were maples, yellow-poplar, mixed oaks, and cherry. Because the relative percentages of other species were small, they were grouped together as "other." The "other" species include ash, basswood, beech, hickory, sweet gum, and walnut. While ANOVA ($\alpha = 0.05$) testing revealed significant differences in normalized sweep between the species groups ($p \leq 0.0052$), a Tukey HSD test showed differences in the means were significant between only oak and maple. The average normalized sweep was greatest for mixed oaks (2.3 inches of sweep) and smallest for maple (1.6 inches). Average sweep deductions followed a similar pattern ranging from 5.9 percent for oaks to 3.9 percent for maples. In addition, oaks resulted in the smallest percentage of straight logs (60.3%) while maples were the straightest (71.2%).

Summary and conclusions

One-third of hardwood logs sampled exhibit measurable sweep or curvature greater than 1 inch.

The average normalized sweep (12-foot log length basis) was 4.1 inches for logs with sweep or curvature greater than 1 inch.

For the 32 percent of logs with measurable sweep, the average log scale deduction for sweep was 13 percent.

Of the major species or species group in the test sample, oak logs exhibited the highest level of sweep and maple the lowest level.

The level of log sweep measured indicates that for approximately 32 percent of the hardwood population, curve sawing will measurably improve lumber yield.

Normalized sweep and small-end log diameter are inversely related. Smaller diameter logs have more severe sweep defects than large diameter logs. Processing of small diameter logs may benefit from curve sawing.

Literature cited

Carino, H., K. Arano, C. Blanche, and M. Patawaran. 2006. Impact of curve sawing on southern pine dimension lumber manufacturing: Part 1. Lumber volume and value yields. Forest Prod. J. 56(7/8): 61-68.

Hamner, P., M. White, and P. Araman. 2006. The effect of curve sawing two-sided cants from small-diameter hardwood sawlogs on lumber and pallet part yields. Forest Prod. J. 56(10):80-85.

Grosenbaugh, L. 1952. Shortcuts for cruisers and scalers. USDA For. Serv. South. For. Exp. Stn. Occas. Pap. 126:24.

Nelson, R. 2001. All about curve sawing. Timber Processing. 23(9): 38-42.

Petree, J. 1998. Sawing on the learning curve. Timberline Magazine. 4(8):8-11.

Rast, E.D., D.L. Sonderman, and G.L. Gammon. 1973. A guide to hardwood log grading. Gen. Tech. Rept. NE-1. USDA Forest Serv., Northeastern Forest Expt. Sta., Broomal, Pennsylvania.

Ronnqvist, M., C. Todoroki, and T. Allsopp. 2000. Usage of 3D geometry descriptions and transformation techniques in log bucking and curve sawing. Ann. Oper. Res. 95:93-113.

Simpson, W.T. and J.R. Shelly. 2000. Method for adjusting warp measurements to a different board dimension. Res. Note. FPL-RN-0273. USDA Forest Serv. Forest Prod. Lab., Madison, Wisconsin.

The Timber Tax Website. 2002. Market Segment Specialization Program (MSP). Hardwood Timber industry. www.timbertax.org/publications/irs/msp/hardwood/chapter1.asp.

Wagner, F.T., T.M. Gorman, K.L. Pratt, and C.E. Keegan. 2002. Warp, MOE, and grade of structural lumber curve sawn from small-diameter Douglas-fir logs. Forest Prod. J. 52(1):27-31.

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.

Woodward, K. 2003. Curve sawing stands the test of time. Southern Lumberman (May).