Impact of elliptical shaped red oak logs on lumber grade and volume recovery

Patrick M. Rappold
Brian H. Bond[*]
Janice K. Wiedenbeck[*]
Roncs Ese-Etame[*]

Abstract

This research examined the grade and volume of lumber recovered from red oak logs with elliptical shaped cross sections. The volume and grade of lumber recovered from red oak logs with low ($e \leq 0.3$) and high ($e \geq 0.4$) degrees of ellipticity was measured at four hardwood sawmills. There was no significant difference ($p = 0.57$) in the percent of No. 1 Common and better grade lumber recovered between the two ellipticity classes across the four sawmills. Differences in the percent of lumber overrun was also found to not be significant ($p = 0.61$) between the two log ellipticity classes. Information collected for this research did illustrate that at several of the sawmills studied yield of lumber from highly elliptical logs could be improved.

Because stumpage prices continue to increase faster than lumber prices, profit margins in the U.S. hardwood sawmill industry have decreased, forcing lumber producers to become more efficient or go out of business (Luppold and Baumgras 1998). Loss of traditional markets and pressure from foreign competition are also forcing sawmills to reexamine methods of increasing productivity and decreasing costs. Among the many ways to improve efficiency in lumber production is to maximize volume and grade recovery from logs. Methods and techniques to maximize lumber recovery from round hardwood logs are well documented, but there is minimal information regarding best sawing practices for nonround, or elliptically shaped, hardwood logs.

Hardwood log ellipticity describes how much the cross section at the small end of a log deviates from a circle. Based upon geometric calculus, ellipticity is calculated using the major and minor axis dimensions of an ellipse, as expressed in Equation [1] (Stewart 1999).

$$e = \frac{\sqrt{(d/2)^2 - (d'/2)^2}}{(d/2)} \qquad [1]$$

where: e = ellipticity; d = length of the major axis; d' = length of the minor axis

A survey of logyards in West Virginia and Ohio found the ellipticity values of logs from this region ranged between 0.30 to 0.45 with the average ellipticity of a log being 0.37 (Bond et al. 2007). Of the red oak logs sampled by Bond et al. (2006) 43 percent had an ellipticity measurement of 0.40 or greater, where the mean difference was 1 to 1-1/4 inches between the major and minor axes (Bond et al. 2007).

Despite the percentage of hardwood logs that are estimated to be elliptical in shape, prior research has not determined if the grade and volume of lumber recovered from hardwood logs is impacted by a log's ellipticity. In a simulation-based study, Maness and Donald (1994) found that with a chip and saw cutting pattern the value of the lumber recovered decreased as the degree of ellipticity in western spruce logs increased. Results from another simulation-based study (Kellog and Warren 1984) concluded that ellipticity had a statistically significant effect on the volume of lumber recovered from western hemlock logs, but was considered inconsequential in comparison to the effect of log taper on lumber yield.

For the present study, the purpose was to determine if the current sawing practices in use by hardwood sawmills should be adjusted to account for nonround red oak logs. The specific objectives of this paper are to: (1) Determine if the percentage of No. 1 Common and better lumber grade recovered between the two ellipticity classes was significant, and (2) Determine if

Table 1. — USDA Forest Service Specifications for Grade 1 Logs. Adapted from Vaughan et al. (1966).[a]

Grading factors	Log grade		
	F1		
Position in tree	Butts only	Butts and uppers	
Scaling diameter (in)	13 to 15	16 to 19	20+
Length without trim (ft)		10+	
Required clear cuttings on each of 3 best faces			
Minimum length (ft)	7	5	3
Maximum number	2	2	2
Fraction of log length required in clear cutting	5/6	5/6	5/6
Maximum sweep and crook allowance			
For logs with less than 1/4 of end in sound defects	15%		
For logs with more than 1/4 of end in sound defects	10%		
Total scaling deduction including sweep and crook		30%	

[a]For a more detailed table refer to: Vaughan, C.L., A.C. Wollin, K.A. Mc-Donald, and E.H. Bulgrin. 1966. Hardwood log grades for standard lumber. Research Paper FPL–63. USDA. Forest Service. 54pp.

Figure 1. — Illustration of the major (d) and minor (d′) axes on an elliptical shaped log.

the percentage of lumber overrun between the two ellipticity classes was significant. Much of this paper focuses on the lumber grades that are No. 1 Common and better because within the hardwood industry these lumber grades are considered to bring the highest return on investment (Cumbo et al. 2003). It is therefore of interest to hardwood sawmill managers as to how elliptical shaped logs affects the yield of the high market value products.

Methods

At four hardwood sawmills, located in Virginia and West Virginia, a total of 160 red oak logs were selected based upon length, diameter, log grade, and degree of ellipticity. To reduce variability the length parameter was limited to logs between 10 and 12 feet with scaling diameters ranging from 14 to 18 inches. All of the logs selected meet the requirements for a Grade 1 Forest Service log (**Table 1**). In addition, logs with double piths were excluded from the sampling selection in an attempt to reduce variability between the test logs.

When quantifying the ellipticity of a log, the major axis (d) and minor axis (d') variables were measured at the small end and inside of the bark (**Fig. 1**). The length of the axes were measured to the nearest 0.25 of an inch with a standard tape measure. Logs with ellipticity measurements of 0.30 and less were classified as having low ellipticity, and logs with ellipticity measurements of 0.40 and greater were classified as highly elliptical logs. The two ellipticity classifications served as treatment factors for the experimental design of this project, and the four sawmills that the logs were sampled from served as blocking factors. Each of the treatment groups contained 20 logs, for a total of 40 logs sampled at each of the four sawmills.

The test logs were systematically followed through the sawmill machine centers, and the volume and grade of lumber recovered from each individual log was recorded. Determination of the lumber grade and volume attributes was done using the lumber inspectors employed by each of the cooperating sawmills.
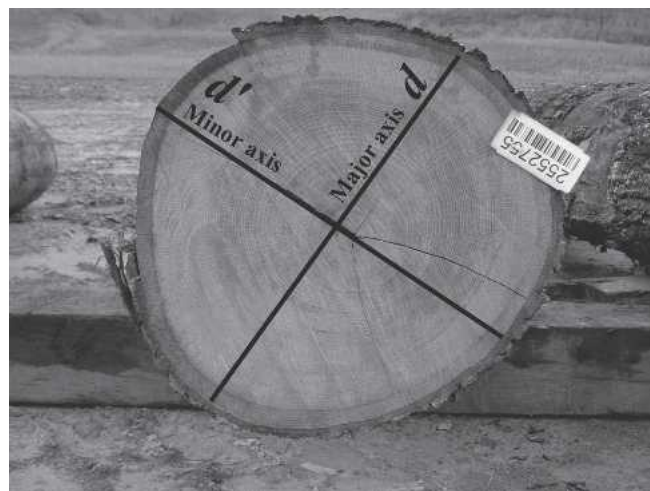
Results and discussion

Because the logs that had been sampled ranged in length between 10 and 12 feet with scaling diameters varying from 14 to 18 inches, the possibility existed that unequal sampling of log sizes between treatment factors (degree of ellipticity) would bias identifying the true magnitude of the treatment effects. A Pearson chi-square statistical test was performed to determine if the distribution of log volumes between the two treatment factors and across the four sawmills was significantly different at an alpha level of 0.05. The FREQ procedure of the Statistical Analysis System was used to execute the Pearson chi-square test (SAS Institute Inc. 2004).

Results from the Pearson chi-square test found that the number of logs with similar log volumes was not equal ($p = 0.01$) between the low and high degree ellipticity treatment factors. These results reinforce the justification for using the four sawmills as blocking factors when testing the effect of degree of ellipticity. The Pearson chi-square test was also used to evaluate the distribution of log volumes between the two treatment factors by sawmill. With the exception of the logs sampled at sawmill C, the number of logs with similar volumes was found to be not significantly different between the two treatment factors (**Table 2**). At sawmill C a greater number of large volume logs were sampled that had low degrees of ellipticity in comparison to the volumes of the test logs classified as having a high degree of ellipticity.

Because of the differences in log volumes sampled between the sawmills and the fact that the manufacturing processes at the four sawmills were not homogenous, information collected for this project was analyzed using a statistical model for randomized complete block designs (RCBD). Through the RCBD statistical model, effects due to the blocking factors (sawmills) are balanced across the treatment factors (Lentner and Bishop 1993). As a result, effects attributed to differences in the manufacturing techniques used and differences in the size of the logs sampled at the sawmills become null. It should be noted, however, that differences in log size remains a limitation of this research because with a RCBD it is preferred, but not necessary, that the experimental units (in this instance,

logs) be homogenous across the blocking factors (Lentner and Bishop 1993).

Analysis of the lumber yield information collected from the sawmills revealed that, on average, a large percentage of the total volume recovered was No. 1 Common and better grade lumber. However, as illustrated in **Figure 2**, logs with a high degree of ellipticity yielded 1.9 percent more No. 1 Common and better grade lumber than logs that were classified as having a low degree of ellipticity. The No. 1 Common and better grade lumber grouping used for this analysis included the FAS and F1F standard lumber grades as designated by the National Hardwood Lumber Association (2003). Grouping for the No. 2 Common and less designation, included lumber graded as No. 3 A and 3B Common. The pallet material classification grouped together all of the pallet cants, 1 by 8, and 1 by 6 material recovered from the logs.

A statistical analysis of the lumber recovery information found that the average percent of No. 1 Common and better grade lumber recovered between logs with low and high ellipticity was not significant ($p = 0.57$). A summary of the results from the statistical analysis is presented in **Table 3**.

Examination of the data collected from each sawmill revealed that in some instances a greater percent of No. 1 Common and better grade lumber was recovered from logs with high ellipticity. As **Figure 3**, shows the highly elliptical logs sampled at sawmill B produced 13.4 percent more volume of No. 1 Common and better grade lumber than the low ellipticity treatment group. Although the recovery values at sawmill C suggest the inverse, these differences may be due in part to the uneven sampling of logs with similar volumes between the two treatment factors at this particular sawmill.

Across all of the lumber grades, there was a 1.9 percent difference in the average volume of lumber recovered per board foot (BF) of log volume processed between the two ellipticity classes. Values used for the log volumes in the lumber overrun analysis were based upon the International 1/4-inch

log scale (USDA FS 1977). As summarized in **Table 4**, an analysis of the average lumber overrun values with the RCBD statistical model revealed that the average lumber overrun values between the two log ellipticity classes were not significantly different ($p = 0.61$). Bias caused by differences in the sampling of log volumes between the ellipticity classes was reduced by using the International 1/4-inch log scale since the accuracy of this scale to estimate the volume of lumber that can be produced from a given log is not affected by log diameter or length (Cassens 2003).

Examination of the average lumber overrun values by individual sawmill suggests that there is opportunity for improving lumber yield from logs with high ellipticity. As **Figure 4** illustrates the average lumber overrun values for the highly elliptical logs are less than that of the low-ellipticity logs sampled at sawmills A and B. There is no clear explanation for why this trend was not uniform across all the sawmills. In terms of machine centers, at sawmills A and D the logs were four-sided at a headsaw before being sent to a line-bar resaw and later to a gangsaw. At sawmills B and C the logs were processed using only a headsaw and a gangsaw. Subsequently, differences in the types of machine center utilized alone does not explain why the same trend in average lumber overrun values does not occur between the four sawmills.

It is of interest to better understand why at sawmills A and B the logs with low ellipticity yielded more lumber than the high elliptical log group while the opposite response occurred at sawmills C and D. Given that previous research (Bond et al. 2007) has revealed that 43 percent of the logs in the Appalachian region can be characterized as highly elliptical the potential exists for sawmill A to loose a considerable amount of lumber by processing highly elliptical logs.

In a scenario where sawmill A processes on average 500 logs per day then hypothetically 215 logs (500 logs × 0.43) of the logs sawn would be highly elliptical. Assuming that the average log size at this sawmill is 100 BF (International 1/4-inch log scale) and using the overrun statistics presented in **Figure 4,** then approximately 106 BF of lumber (1.058 × 100 BF) would be recovered from one highly elliptical log in comparison to the estimated 117 BF (1.169 × 100 BF) of lumber yielded from one low-ellipticity shaped log. One day's production volume of lumber from logs with high ellipticity would be 22,790 BF (106 BF × 215 logs) and 33,345 BF (117 BF × 285 logs) from low-ellipticity logs. Using the No. 1 Common and better lumber statistics for sawmill A that were presented in **Figure 3**, it can be generalized that the highly elliptical logs would only yield 15,885 BF (22,790 BF × 0.697) of No. 1 Common and better grade lumber while logs with low ellipticity would produce 23,675 BF (33,345 × 0.710). The differences in the volume yield of No. 1 Common and better grade lumber between the two log ellipticity classes would also have an effect on the value of the lumber sawn.

The published market value in the July 22, 2006 edition of the Hardwood Market Report for 1-inch thick green No. 1 Common red oak lumber from the Appalachian region was $625 per 1,000 BF. Following the same scenario, the estimated

Table 2. —Test statistics and probability values resulting from the Pearson chi-square test on the number of logs sampled with similar log volumes between the low and high degree ellipticity treatment factors by sawmill.

Sawmill	Pearson chi-square test statistic[a]	Pr ≥ ChiSq
A	13.62	0.11
B	11.62	0.23
C	15.68	0.03
D	2.87	0.99

[a] $\alpha = 0.05$
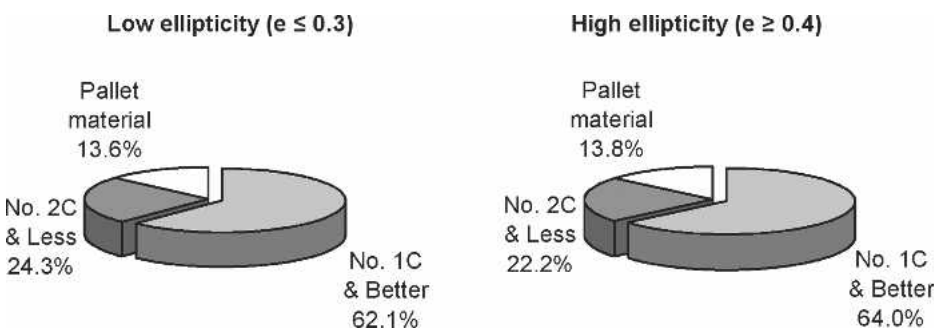
Figure 2. — Average percentage of total lumber volume recovered from individual logs by degree of ellipticity.

Table 3. — Summary of the results for the statistical test on the percent of No. 1 Common and better lumber grade recovered as a function of log ellipticity.

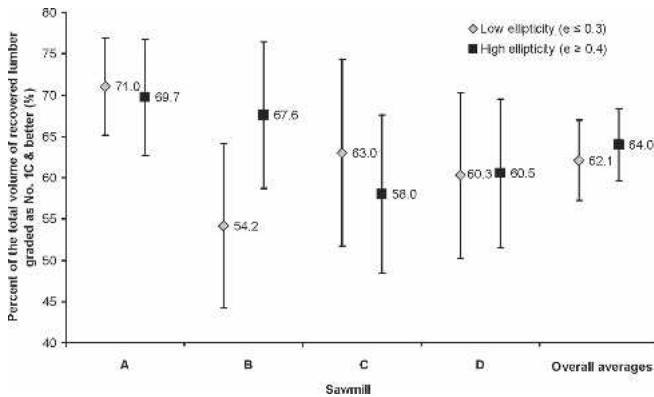| Source	SS	df	MS	F Value	Pr > F
Degree of ellipticity	138	1	138	0.32	0.57
Sawmill	2877	3	959		
Error	67270	155	434		
Total	70285	159			

Figure 3. — Average percent of the total volume of recovered lumber graded as No. 1 Common and better by sawmill and across all four sawmills. The error bars represent the 95 percent confidence interval for μ.

Table 4. — Summary of the results for the statistical test on the average lumber overrun/underrun values as a function of log ellipticity.

Source	SS	df	MS	F Value	Pr > F
Degree of ellipticity	56	1	56	0.26	0.61
Sawmill	2567	3	856		
Error	33814	155	218		
Total	36437	159			

value of the No. 1 Common and better grade lumber yielded from the highly elliptical logs would be $9,928.13 (15,885 BF × $0.625). In contrast the volume of No. 1 Common and better grade lumber produced from logs with low ellipticity would be worth $14,796.88 (23,675 BF × $0.625). These values are conservative estimates since the market prices for the FAS and F1F lumber grades are not included in this hypothetical scenario. The total market value of the No. 1 Common and better grade lumber produced in the above scenario would be $24,725.01. If the log sawing procedures at sawmill A could be improved upon to increase the overall yield of lumber from highly elliptical logs to that of low-ellipticity logs the value of the lumber could roughly be worth $25,959.38 by following the same mathematical logic presented above. Although there is only a $1,200 difference in market value between the two scenarios if compounded over a 4 day work week the difference would accumulate to around $4,800. As this example illustrated there is a financial incentive for hardwood sawmills to more closely examine how sawing highly elliptical logs is affecting their lumber yields.

Summary and conclusions

The purpose of the research presented in this paper was to determine if the current sawing practices in use by hardwood
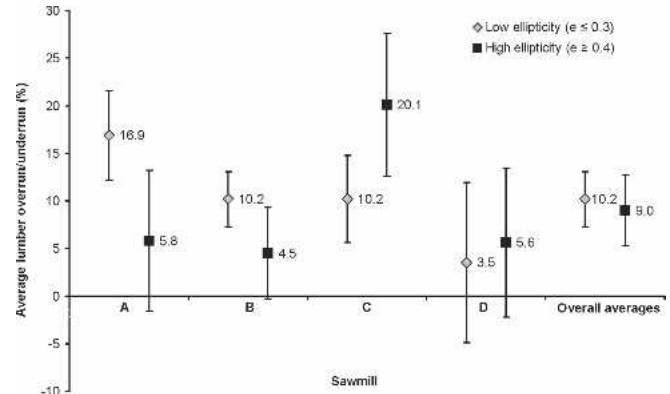

Figure 4. — Average lumber overrun/underrun values by sawmill and across all four sawmills. The International 1/4-inch log scale was used for the log volume values in the calculation of the lumber overrun/underrun statistics. The error bars represent the 95 percent confidence interval for μ.

sawmills should be adjusted to account for non-round logs. Analysis of the information collected from four hardwood sawmills revealed that statistically there was no significant difference ($p = 0.57$) in the percent of No. 1 Common and better grade lumber yielded from red oak logs with low ($e \leq 0.3$) or high ($e \geq 0.4$) degrees of ellipticality. Differences in the percent of lumber overrun was also found to not be significant ($p = 0.61$) between the two log ellipticity classes. Despite the results from the statistical analyses, the information collected did illustrate that at several of the sawmills studied there was opportunity to improve lumber yields from highly elliptical logs.

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