Measuring the Effect of Internal Log Defect Scanning on the Value of Lumber Produced

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Abstract

In this article, we report on the effect of internal log defect scanning on the gain in lumber value recovery for five hardwood species, consisting of black cherry, hard maple, yellow poplar, red oak, and white oak logs. A total of 29 logs, 6 logs per species and 2 logs each for log Grades 1, 2, and 3, were scanned with a medical X-ray computed tomography scanner to acquire their cross-sectional images. The one exception being for red oak logs, for which we scanned two Grade 1 logs, one Grade 2 log, and two Grade 3 logs. These logs were then sawn in the sawmill to determine the actual value recovered from each log. Virtual logs constructed with the scanning images of these logs were then sawn on the computer using the TOPSAW software. Based on simple live sawing simulations, overall the average value gain for all species and grades was 46%, while the gains for black cherry, hard maple, yellow poplar, red oak, and white oak were 42, 33, 83, 24, and 60 percent, respectively. The average gains for Grades 1, 2, and 3 logs were 27, 47, and 97 percent, respectively. Regression analysis of the gains indicated that while there are no significant differences among the species, the gain for Grade 3 logs was significantly different from other log grades.

Hallock and Lewis (1971) developed the best opening face (BOF) sawing algorithm for sawing softwood lumber. Their algorithm was so successful that it resulted in an annual increase in softwood lumber volume recovery of at least 1 billion board feet (USDA Forest Service 2009). The success of BOF encouraged researchers in wood technology to develop a similar algorithm for hardwood sawmills. Early on, it was quickly recognized that for hardwood sawmills, the goal is value rather than volume maximization from each log. To accomplish this goal requires (1) the ability to acquire information about not only the external size and shape but also the type, location, and size of various internal defects in a log and (2) a sawing optimization software to maximize the value of lumber produced based on both the external and the internal information of the log.

Sawing simulations were first developed and used in the 1960s to study the effect of sawing methods on the grade and value of lumber produced (Peter and Bamping 1962, Peter 1967, Tsolakides 1969). Richards and his associates carried out sawing simulation studies on hypothetical log data (Richards 1973, 1977, 1978; Richards et al. 1978, 1979; Adkins et al. 1979). Contrary to the standard practice of grade sawing, these studies concluded that considerable value could be gained by live sawing hardwood logs that do not have an excessive amount of heart rot or other large core defects. To gain the full potential of live sawing, the wide central boards must be skillfully ripped for grade (Richards et al. 1980).

Harless et al. (1991) and Steele et al. (1993, 1994) addressed the criticism that these conclusions were based on flawed hypothetical logs by manually digitizing 24 red oak logs with the approach first advanced by Tsolakides (1969). They then carried out sawing studies with the digitized cross sections of actual logs. From these efforts, Steele et al. (1993) concluded that there is a conflict between value maximization and volume maximization. BOF algorithm, based on the external shape and size of the log to maximize the volume of the lumber produced, therefore would not maximize the value of lumber produced. They also found that the optimal rotational orientation of the log and depth of the opening cut produced a lumber value that was significantly higher than the average of the lumber value produced of all positions within the optimal orientation.

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Chang et al. (2005) followed up on the study by Steele et al. (1993) using the scanning images of seven red oak logs acquired with an X-ray computed tomography (CT) scanner and showed that the optimal orientation of the log and depth of the opening cut outproduces the average of all possible combinations of log orientation and depth of opening cut by 14.7 to 19.5 percent, depending on the lumber prices. More important, the nondestructive acquisition of the log images allowed them to let the sawmill cut the actual logs and determine the potential gains of log scanning over actual sawmill performance. This mill-based study showed that, based on the results of seven logs, live sawing could potentially increase the value of lumber produced over a sawmill's actual recovery by 14 to 28 percent (Chang et al. 1997). Because of the small size of the sample, a larger size study is needed to verify the potential gains.

Methods

In this study, we report the results of just such a study based on 29 logs of five different species. The sample included black cherry (*Prunus serotina* Ehrh.), hard maple (*Acer saccharum* Marsh.), yellow poplar (*Liriodendron tulipifera* L.), red oak (*Quercus rubra* L.), and white oak (*Quercus alba* L.). All logs are believed to have come from northeastern Indiana. With the exception of red oak, the sample consisted of two logs each in Forest Service log Grades 1, 2, and 3. For red oak, there were two Grade 1 logs, one Grade 2 log, and two Grade 3 logs. In the summer of 2007, these logs were scanned with a GE HiSpeed CT/I medical X-ray scanner in a mill setting and then cut in the sawmill to the best ability of the sawyer. The sawing pattern used by the sawyer was, in almost all cases, grade sawing. The head saw on which the boards were sawn had an optimizing system based on log profile detection with lasers—the current ''state of the art'' in optimization in the hardwood sawmill industry.

At the same time, the acquired log images were processed to construct the virtual logs, which were then sawn with the TOPSAW sawing optimization software (Chang and Guddanti 1995, Guddanti and Chang 1998) to determine the maximum lumber value possible from each log under live sawing. Live sawing was chosen over all other possible sawing patterns because it represents the special case of all other sawing patterns. Thus, the results from live sawing would represent a conservative low-end estimate of the potential gains. Because 4/4-inch lumber represents the bulk of the hardwood sawmill production and to simplify the comparison, only 4/4-inch lumber was cut in this study. The specific prices used for various grades of lumber by species are shown in Table 1.

Table 1.—The prices ($ per thousand board feet) of 4/4-inch lumber, by species and grade, used in the study.[a]

	Grade					
Species	FAS	Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Black cherry	2,265	2,265	1,305	620		
Hard maple	1,580	1,580	1,000	630	345	300
Red oak	1,020	1,020	610	510	365	330
White oak	1,320	1,320	625	465	365	330
Yellow poplar	735	735	345	265		

[a] Hardwood Review (2007).

Results

As shown in Table 2, sawing optimization consistently outperforms the actual mill production. When all species and all grades were included, sawing optimization resulted in an overall potential gain of 46 percent. Comparisons of the results for each species individually indicated a gain of 42 percent for black cherry, 33 percent for hard maple, 24 percent for red oak, 60 percent for white oak, and 83 percent for yellow poplar. Within a particular log grade, the overall gains were 27, 47, and 108 percent for Grade 1, 2, and 3 logs, respectively. It should be pointed out that for one of the Grade 3 yellow poplar logs, sawing optimization exceeded the actual value of lumber produced nearly 23-fold. Even after this outlier is excluded from the analysis, the overall gain for Grade 3 logs was still a respectable 97 percent. In terms of individual species, for Grade 1 logs the gains were 20 percent for black cherry, 21 percent for hard maple, 8 percent for red oak, 83 percent for white oak, and 23 percent for yellow poplar. For Grade 2 logs, they were 45, 34, 22, 42, and 99 percent, respectively. The Grade 3 logs experienced the most dramatic gains in value. Even after the outlier was excluded, the gains were 194 percent for black cherry, 75 percent for hard maple, 67 percent for red oak, 46 percent for white oak, and 221 percent for yellow poplar. Clearly, for poorer-quality sawlogs the ability to properly orient the log and place the saw at the right depth for the opening cut, which effectively shifts some of the boards to higher grades, can result in a dramatic gain over the current laser-based optimization used in the comparison sawmill.

The fact that there are no prices assigned to 3A Common black cherry and yellow poplar lumber contributed significantly to the dramatic gains for Grade 3 logs of these two species. For example, for the Grade 3 yellow poplar log that resulted in a 23-fold increase in the value of lumber produced, the boards actually produced by the sawmill

Table 2.—The value recovery ($) from actual mill cuts versus TOPSAW optimization and X-ray CT scanning.

	All species	Black cherry	Hard maple	Red oak	White oak	Yellow poplar
All grades						
Mill	2,956	993	755	389	456	363
TOPSAW	4,309	1,408	1,008	484	730	664
Gain (%)	46	42	33	24	60	83
Grade 1						
Mill	1,558	512	391	252	193	210
TOPSAW	1,973	617	473	272	353	258
Gain (%)	27	20	21	8	83	23
Grade 2						
Mill	1,000	417	248	39	175	121
TOPSAW	1,470	603	331	47	248	240
Gain (%)	47	45	34	22	42	99
Grade 3						
Mill	398	64	116	98	88	32
TOPSAW	829	188	203	164	128	166
Gain (%)	108	194	75	67	46	418
Grade 3, outlier removed						
Mill	395	64	116	98	88	29
TOPSAW	777	188	203	164	128	93
Gain (%)	97	194	75	67	46	221

Table 3.—Results of a regression analysis of percent gains by individual logs.[a]

Test	Intercept	G2 coefficient	G3 coefficient	YP coefficient	RO coefficient	HM coefficient	WO coefficient	R^2
Gain (with spp.)	0.588 (0.402)	0.261 (0.382)	1.022[b] (0.382)	0.239 (0.503)	−0.659 (0.503)	−0.519 (0.478)	−0.259 (0.478)	0.827
Gain (without spp.)	0.323 (0.262)	0.307 (0.281)	0.961[b] (0.381)					0.828

[a] Values in parentheses are standard errors. G2 = dummy variable for Grade 2 logs, G3 = dummy variable for Grade 3 logs, YP = dummy variable for yellow poplar logs, RO = dummy variable for red oak logs, HM = dummy variable for hard maple logs, WO = dummy variable for white oak logs.
[b] Significant at 1 percent level.

included only two No. 2 Common boards while the others were 3A Common or culls (thus assessed as having no value). On the other hand, the CT scan–based sawing conducted using the TOPSAW produced six FAS and five No. 1 Common boards.

To obtain further insights into the gain by species and log grade, the percent gains by individual logs were analyzed. The regression analysis conducted using the results for 28 logs (yellow poplar outlier removed) indicates that statistically there is no significant difference in gains among the species (Table 3).

On the other hand, there is a significant difference in gains between Grade 3 logs and the other two log grades. When the species variables were dropped to focus only on the impact of the log grades on the percent gains, the results, also shown in Table 3, were similar to those obtained when the species variables were included in the regression.

Our result that log grades make a difference in percent gains in lumber value is different from that reported by Steele et al. (1993), who found that there was no significant difference in the gain among all log grades. It is important to note that results of Steele et al. (1993) were based on a comparison of the optimal solution against the average of all possible solutions, while our results are based on the comparison of the optimal solution against actual mill results. The implication of our finding is far reaching in that once an internal defect–based sawing optimization becomes commercially available, sawmills could realize significant gains in lumber value recovery from lower grades of logs regardless of species. Given the abundance of Grade 3 logs and the much lower prices paid for these logs, sawmills could increase their profit significantly. At the same time, the more efficient conversion of low-grade logs into lumber could reduce the amount of timber harvested, thus leaving more trees in the woods to mature and improve their log quality. The better quality of lumber produced as a result of knowledge of the internal defects in logs would result in more satisfied consumers.

Conclusions

In this study the potential effect of the knowledge of internal defects on the value of lumber produced is measured against the value results obtained at a sawmill. The potential overall gain is around 46 percent, with no significant differences among the five species tested in the study. On the other hand, there is a significant difference among the three log grades, with Grade 3 logs producing over twice the gain of the overall average.

Once an industrial X-ray CT log scanner becomes commercially available, the sawing optimization based on knowledge of internal defects has the potential to benefit individual sawmills by increasing their profits, the nation as a whole by enhancing its resource conservation, and the consumer with improved quality of lumber.

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