Hardwood Log CT Scanning - Proof of Concept

by

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Abstract

Sixty logs were specifically selected to include 12 logs per species of Black Cherry, Yellow Poplar, Red Oak, White Oak and Hard Maple. Groups of 12 included four logs per each of three log grades. The four logs per log grade per species were selected to make two pairs – pair being a close match in diameter, length, location within a tree and defects. Logs were 10' to 16' long and up to 16" in diameter.

All logs were scanned using a CT x-ray scanner. TOPSAW program was used to find sawing solutions for half of the logs (one of each matching pair). A sawing study was conducted where half the logs were processed into 4/4 lumber using the TOPSAW sawing solution and the other half was processed using normal mill practices. The scanning and sawing process as well as limited evaluation of collected data will be presented. To our knowledge, this is the largest study of full-size hardwood logs to date.

Introduction

For the longest time, sawmillers have dreamed about having the ability to see through the log. They believe that if they can see what is inside a log, better sawing decision can be made to increase the value of lumber produced. Over the last 20 years, various scanning technologies have been tried to scan logs for internal defects. They include X-ray CT, magnetic resonance imaging (MRI, also known as nuclear magnetic resonance -- NMR), and ultrasound. The X-ray CT technology has emerged as the most viable technology for the log scanning purpose (Chang 1992). Wood technologists began scanning logs with X-ray CT scanner to locate and identify internal defects as soon as it became commercially available. Early efforts include Benson-Cooper et al. (1982), Birkeland and Holoyen (1987), Burgess (1985), Cown and Clement (1983), Funt and Bryant (1987), Miller (1988), Onoe et al. (1984), Roder, Scheinmann and Magnuson (1989), Shadboolt (1988), Taylor et al. (1984), and Wagner et al (1989). Recently, Schmoldt et al. (2000) provided an update of the research in X-ray CT log scanning during the 1990s.

Objective

The overall goal of the Hardwood Scanning Center is to increase the competitiveness of the hardwood industry and conserve the hardwood resource through increased conversion efficiency. We aim to accomplish this goal through development of technologies which will enable hardwood industry to "see inside a tree" and use this information to make better sawing decisions.

The specific objective of this study is to examine the performance of CT scanning technologies as compared to traditional hardwood log sawing methods.

Methods

In this study, we report the results of a study based on 29 logs of 5 different species. They include black cherry, hard maple, yellow poplar, red oak and white oak. With the exception of red oak, each species consists of two logs each in log Grades 1, 2, and 3. For red oak, there are two Grade 1 logs, one Grade 2 log, and two Grade 3 logs. In the summer of 2007, these logs were scanned with a medical X-ray CT scanner in a mill setting and then cut in the sawmill to the best ability of the sawyer. 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. Due to the fact that 4/4" lumber represents the bulk of the hardwood sawmill production and to simplify the comparison, only 4/4" lumber was cut in this study.

Results

As shown in Table 1, sawing optimization consistently out-performs the actual mill production. When all species and all grades are included, sawing optimization results in an over-all potential gain of 46%. Comparisons of the results for each species individually indicate a gain of 42% for black cherry, 33% for hard maple, 24% for red oak, 60% for white oak, and 87% for yellow poplar. Within a particular log grade, the over-all gains are 27%, 47%, and 118% respectively for Grade 1, 2, and 3 logs. 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 30 fold. Even after this outlier is excluded from the analysis, the overall gain for Grade 3 logs is still a respectable 97%. In terms of individual species, for Grade 1 logs the gains are 20% for black cherry, 21%

for hard maple, 8% for red oak, 83% for white oak and 23% for yellow poplar. For Grade 2 logs, they are 45%, 34%, 22%, 42%, and 99%, respectively. The Grade 3 logs experienced the most dramatic gains in value. Even after the outlier is excluded, the gains are 194% for black cherry, 75% for hard maple, 67% for red oak, 46% for white oak, and 221% 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 could results in a dramatic gain over the current sawmill technology.

Table 1. The results of actual mill cuts and TOPSAW optimization

		all	BC	HM	RO	WO	YP
all grades	Mill	2956	993	755	389	456	363
	TOPSAW	4309.22	1408.47	1007.59	483.52	729.62	680.02
	Gain (%)	46	42	33	24	60	87
Grade 1	Mill	1558	512	391	252	193	210
	TOPSAW	1973.22	616.72	473.2	272.28	353.41	257.61
	Gain (%)	27	20	21	8	83	23
Grade 2	Mill	1000	417	248	39	175	121
	TOPSAW	1470.3	603.41	331.16	47.49	247.8	240.44
	Gain (%)	47	45	34	22	42	99
Grade 3	Mill	398	64	116	98	88	32
	TOPSAW	865.7	188.34	203.23	163.75	128.41	181.97
	Gain (%)	118	194	75	67	46	469
Grade3 -1	Mill	395	64	116	98	88	29
	TOPSAW	776.77	188.34	203.23	163.75	128.41	93.04
	Gain (%)	97	194	75	67	46	221

To obtain further insights into the gain by species and log grade, the percentage gains by individual logs were analyzed without the outlier. As shown in Table 3, the results of the regression analysis of all 29 logs indicate that statistically there is no significant difference in gains among the species. On the other hand, there is a significant difference in gains between grade 3 logs and the other two log grades. This latter result is different from that reported by Steele et al. (1993) indicating that there is no significant difference in the gain among all log grades. It is important to note that results Steele et al. (1993) are 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. 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. At the same time, the better quality of lumber produced as a result of knowledge of the internal defects in logs would result in more satisfied consumers.

Summary

In this study the potential effect of the knowledge of internal defects on the value of lumber produced is measured against actual mill cuts. The potential over-all gain is around 46%, 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 over-all average.

Once an industrial X-ray CT log scanner becomes commercially available, the sawing optimization based on knowledge of internal defects has a potential to benefit the 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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