The value versus volume yield problem for live-sawn hardwood sawlogs

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Abstract

The potential conflict between value and volume maximization in sawing hardwood sawlogs by the live sawing method was analyzed. Twenty-four digitally described red oak sawlogs were sawn at the log orientation of highest value yield. Five opening face sawlines were iteratively placed in the sawlog at 1/4-inch intervals and lumber grades, volumes, and values from completely sawing the log at each opening face position were determined. Volumes were computed for several sawing positions of interest: maximum and minimum volume, minimum opening position, mean volume, and centered solution. Dollar values and distances from minimum opening position were also determined for these sawing positions of interest. Statistical comparisons of these variables showed that the conflict between value and volume yield was significant. A potential average loss of $2 per sawlog was indicated if volume yield was maximized at the expense of value yield. Results also indicated that a precise knowledge of internal defect location is apparently required to obtain maximum value yield. An internal scanning system will be required to obtain the needed defect location information.

In North American softwood sawmills, electronic devices are frequently used to aid the sawyer in making log breakdown decisions. Most of these devices are based on the Best Opening Face (BOF) concept for placement of the initial sawline (1,4). Despite the success of BOF technology in softwood sawmills, application in hardwood sawmills has been limited. This study examined the potential conflict between lumber volume and lumber value maximization when hardwood sawlogs are sawn.

Research has shown that the potential volume yield improvement from BOF decisions for sawing hardwood logs is only slightly less than that for sawing softwood logs (10). The actual volume yield increase from BOF decisions in hardwood sawmills has been estimated to be 6.3 percent (11). The BOF principle relies on an iterative procedure to determine the volume maximizing initial opening face distance from log center. This iterative procedure tests numerous initial opening face distances from log center for a given sawing pattern. These solutions begin at an opening face position where the first board face sawn will be of the minimum acceptable dimension. The complete simulated sawing of the log is performed at this minimum opening face position. Subsequent opening face positions are tested by reducing the opening face distance from log center by arbitrarily selected increments. The distance over which the opening face position is tested is the thickness of one piece of lumber plus the kerf width (4).

Maximum volume yield is attained at the initial minimum opening face position for only a small percentage of BOF solutions (13). For this reason, maximum volume yield is generally obtained for some opening face position closer to log center than that of the minimum opening face. In fact, it has been shown that the highest yielding BOF position is generally

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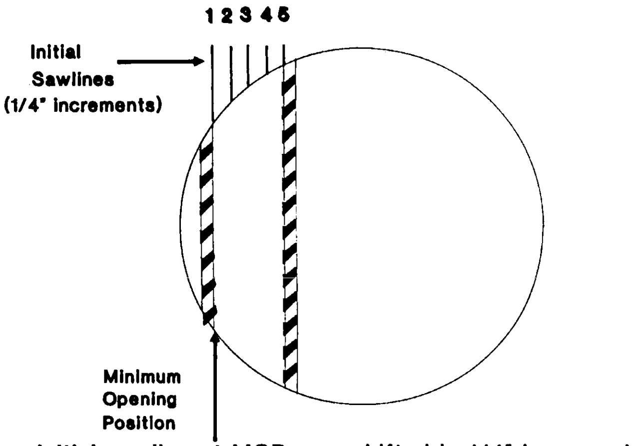

Figure 1.— Sawlog cross section showing the minimum opening position (MOP) and the four incremental 1/4-inch movements of initial opening position toward log center.

obtained by centering the sawing pattern in the sawlog (12,13).

The most numerous defect types in sawlogs are knots. Knots normally occur near the center of the log and decrease in frequency as the distance from log center increases. Therefore, as sawlines are moved toward log center they will intersect with knots more often. The centering of the sawing pattern, which has been shown to maximize volume yield, is achieved by placing the initial opening face sawline closer to log center than is required to obtain a minimum opening face. Therefore, volume maximization may move sawlines to positions that more frequently intersect knots with a resulting reduction in lumber value yield.

Past research has examined hardwood log orientation to determine the influence of defect placement on total lumber value (2,7-9,14,15). A recent study of this type showed a significant 10 percent increase in lumber value for best log orientation (14). All studies to date, however, opened the sawlog only at the minimum opening face, and multiple opening face positions were not tested at each log orientation. The change in lumber value resulting from moving the initial opening face position toward log center to maximize volume yield has, therefore, not been considered in past studies.

Sawlogs are sawn in most hardwood sawmills by the grade-sawing method. However, these grade-sawing hardwood sawmills will often live saw low value logs, from which little high-grade lumber is expected. Live sawing is a fast method to break down the log if it appears that grade sawing cannot be used to increase lumber value. A few hardwood sawmills exclusively employ the live sawing method or an adaptation of the live sawing method, which involves slabbing the log on the headrig followed by processing the resulting two-, three-, or four-sided canton a resaw.

The objective of this study was to determine the significance of the potential conflict between lumber volume and value maximization when live sawing hardwood sawlogs.

Analytical procedures

The live sawing method was analyzed to simplify this initial examination of value versus volume yield. A computer simulation model of the live sawing method was available from a previous study and the assumptions underlying its performance have been described (2). In the previous study, the simulation model opened the log at an initial minimum opening face. For this study, the model was modified to open additional opening face positions in the direction of log center at the same rotational position to determine the highest volume yielding BOF position at that face.

A database of 24 digitally described red oak (*Quercus* spp.) sawlogs was available from a previous study (14). The 24 sawlogs were all 12 feet (3.7 m) long and had been selected to be approximately 16 inches (40.64 cm) in diameter. The sample logs were selected to be as round in cross section as possible. Eight logs in each of the USDA Forest Service hardwood log grades (16) were selected to allow between-grade comparisons.

This study followed the BOF concept of repetitively simulating log sawing to determine the distance from log center at which to open the sawlog for maximum volume. A minimum opening face distance was selected and the log was completely sawn by the simulated live-sawing method. The opening face was moved toward log center by 1/4 inch (0.63 cm) and the log was again completely sawn by simulation. Lumber from each simulated sawing was edged and graded, the board footage was computed, and a value was assigned based on lumber grade and volume. The 1/4-inch incremental movements toward log center were chosen because the sawlogs were described by a three-dimensional array consisting of 1/4-inch units. As Figure 1 shows, four incremental movements toward log center were performed and resulted in the testing of five opening face positions. The lumber was sawn to a thickness of 1.00 inch (2.54 cm) with a 1/4-inch kerf width.

The search for BOF position was carried out at the rotational angle for each log that gave the highest value lumber for the particular minimum opening face selected (13). Sawing procedures recommended by Malcolm to obtain highest value were applied (5). Two minimum opening face dimensions were tested. The smallest minimum opening position (MOP) face width tested was 3 inches (7.6 cm) wide by 8 feet (2.4 m) long. The second MOP face width tested was 6 inches (1 5.2 cm) wide by 8 feet (2.44 m) long. The second face width was chosen in order to determine the potential influence of a widely different opening face width on the value versus volume relation.

Value and/or volume yields were determined and compared for several sawing positions of interest in this study. These sawing positions of interest will be

TABLE 1. — *Lumber prices by grade assigned to lumber produced by the sawing simulation*[a]

Grade	Price
	($)
FAS	790
SEL	690
1C	510
2C	250
3A	195
3B	150

[a]Source: *Hardwood Market Report,* Jan 14, 1989.

termed 'sawing position' to simplify the terminology. Past research on BOF position has concentrated on locating the maximum volume or value position for each sawlog. For comparative purposes, value and volume for additionally defined positions were also investigated in this study. Information on value and volume yields at the initial MOP, at the position of minimum volume yield, and at the position of minimum value yield were determined. The mean volume and corresponding mean values obtained for all positions tested were computed. The minimum value and volume were also determined. The centered solution method of volume maximization developed by Steele and Wengert (11,13) for ideal log forms was also tested for the real-log shapes in this study. For this purpose, the centered solution values and volumes were also determined.

Lumber sawn by the sawing simulation was graded according to National Hardwood Lumber Association rules (6) with hardwood lumber grading software developed by Klinkhachorn et al. (3). Prices assigned by lumber grade in a previous study (14) are given in Table 1. Use of these prices will allow interested readers to compare the results of the two studies.

Experimental design

A split-plot experimental design was developed for this analysis. The whole-plot factor was log grade with the subplots consisting of each log. The subplot factor was sawing position. Whole plots had a completely randomized design, and subplots were randomized complete blocks. The treatment structure was a full factorial arrangement with the factors being log grade and sawing position of interest.

All comparison-of-means tests were performed by the least significant difference method. Both analysis of variance and comparison-of-means tests were at the 0.05 level of significance. Fisher's protected t-test was utilized prior to performing comparison-of-means tests. By this procedure, means comparisons were not performed if the variables were not significant in the analysis of variance (9).

The model to test the volume and value comparisons is given as Model 1:

$$D = \beta_0 + \beta_1 G + \beta_2 L(G) + \beta_3 SP + \beta_4 G{*}SP$$

where:

- D = respective dependent variables of value, volume, or distance from MOP, depending on the variable of interest
- G = log grade
- $L(G)$ = log within grade
- SP = sawing position[1]
- $G{*}SP$ = term representing interaction between log grade and sawing position

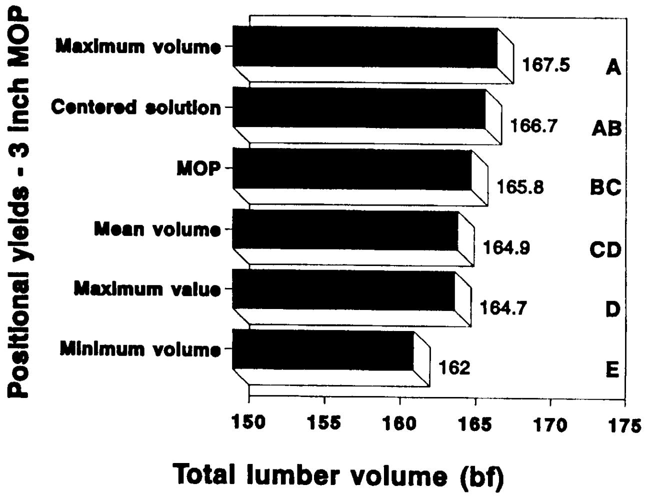

Figure 2. — Lumber volume yields for a 3-inch MOP by sawing position. Results of comparison-of-means tests are indicated by letters on the right side of the graph. Sawing position values with different letters differed significantly.

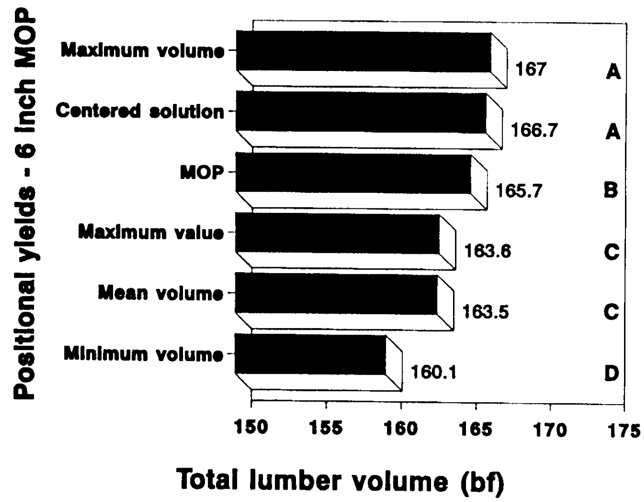

Figure 3. — Lumber volume yields for a 6-inch MOP by sawing position. Results of comparison-of-means tests are indicated by letters on the right side of the graph. Sawing position values with different letters differed significantly.

[1]Sawing position is a generic term standing for the sawing positions of interest being analyzed as a group at the time. Three groups of sawing position variables were analyzed in this study. Maximum volume, centered solution volume, MOP volume, mean volume, and volume at maximum value and minimum volume formed one *SP* group. The second *SP* group consisted of the respective values of lumber obtained for the variables included in the first SP group. Likewise, the third SP group was comprised of the mean distances (in.) from MOP for the variables in the first *SP* group.

Results

*G*SP* was not significant in any of the analysis-of-variance tests. Absence of interaction indicated that examination of the effects of the class variables was appropriate (9). *SP* was significant in each of the analysis-of-variance tests. This satisfied the requirements of Fisher's protected t-test and allowed performance of the subsequent separation-of-means tests for sawing position.

Figures 2 and 3 give the respective volume yields by sawing position (maximum volume, centered solution, MOP, mean volume, maximum value, and minimum volume) for the 3- and 6-inch (7.6- and 15.2-cm) MOP face widths, respectively. Figures 2 and 3 show that the maximum volume board footage yield did not differ significantly from that of the centered solution yield for either the 3- or 6-inch MOP. For the 6-inch MOP, the centered solution volumes differed significantly from MOP volumes. The maximum volume solution had significantly higher board footage yields than the MOP volume yields for both the 3- and 6-inch MOPS. The mean volume and maximum value board footage yields were significantly lower than those for maximum volume, centered solution, and MOP positions for the 6-inch MOP solution. This result was the same for the 3-inch MOP except that mean volume yield did not differ significantly from the MOP yield. The mean volume and maximum value board footage yields did not differ significantly between themselves. The minimum volume yield was the significantly lowest yielding position of those tested.

The volumes produced at the maximum volume position and at the maximum value position differed significantly. This result indicates that maximizing value will sacrifice an average of approximately 3 board feet for about a 2 percent average loss in yield for the 3- and 6-inch MOPS. For each log sawn for both MOPS, the sawlog at either of the MOPS would obtain significantly higher volume yield than that obtained by the maximum value solution. A volume yield equivalent to that at the maximum value position could be obtained by opening the log at random, as evidenced by the lack of significant difference between the mean volume and maximum value yields. The volume yield at maximum value is significantly higher than that of the minimum volume yield, however.

Employing the centered solution position to maximize volume yield may be practical, as indicated by the lack of significant difference between the centered solution and maximum volume yields for both MOPS. However, for the 3-inch MOP, the centered solution volume yields did not differ significantly from MOP volume yields, which raises some question about the reliability of the centered solution as a proxy for BOF position.

Further information on the centered solution positions as a substitute for the maximum value position is given in Figures 4 and 5. These results on the relative value yield by sawing position show that the centered solution position values did not differ from the maximum volume positions. Apparently, the centered solution could be a rapidly computed substitute to determine the volume maximizing BOF position without significant loss of lumber value. However, sawing to the MOP position is as effective in maximizing value as sawing at either the centered solution or the maximum volume position. For both the 3- and 6-inch MOP, the mean value position did not differ significantly from the centered solution and maximum volume yields, which indicates that the log could be opened at random, within the 1-inch range in which opening face position was tested, to give value yields equivalent to those from opening the log at the computed centered solution or maximum volume posi-

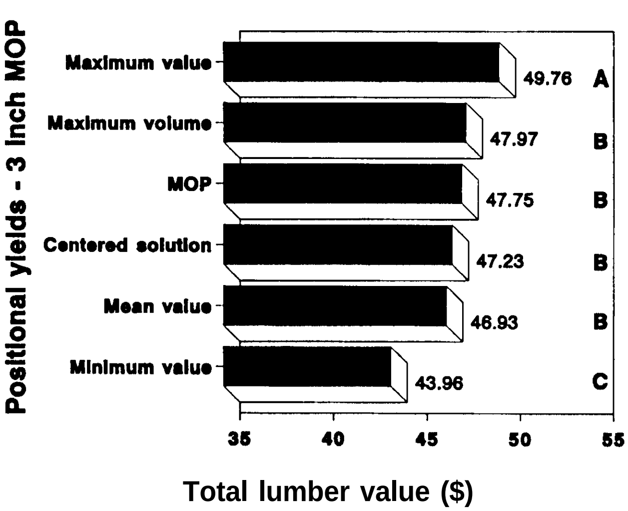

Figure 4. — Lumber value yields for a 3-inch MOP by sawing position. Results of comparison-of-means tests are indicated by letters on the right side of the graph. Sawing position values with different letters differed significantly.

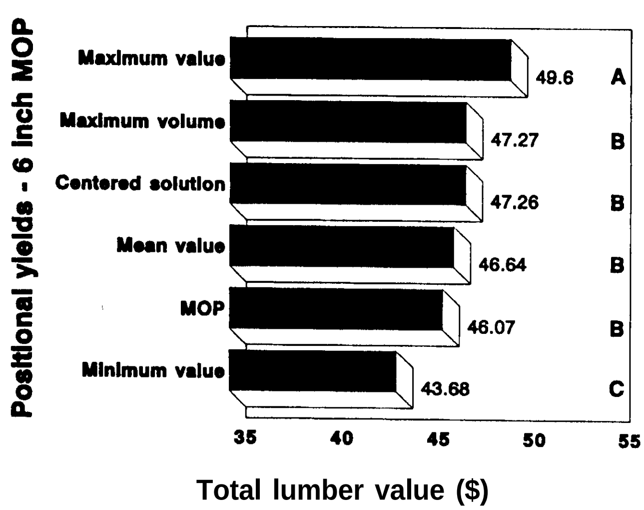

Figure 5. — Lumber value yields for a 6-inch MOP by sawing position. Results of comparison-of-means tests are indicated by letters on the right side of the graph. Sawing position values with different letters differed significantly.

tions. The value results of Figures 3 and 4 show that the minimum value position had the significantly lowest value.

Figures 4 and 5 show that the maximum value yields for both the 3- and 6-inch MOPs were significantly higher than the value at maximum volume. For the 3-inch MOP, the difference was 3.7 percent and for the 6-inch MOP, the difference was 4.9 percent. The mean value difference for both MOPs amounted to about $2 per sawlog. Therefore, using BOF procedures to maximize volume in a hardwood sawmill could result in a significant lumber value loss.

Figures 6 and 7 give the relative locations of the sawing positions in terms of mean distance from each MOP. The results for the 3- and 6-inch MOPs were similar. For both, the minimum volume position was found at the significantly greatest distance from the MOP position, which indicates that the 1-inch range of distance, within which initial opening face positions were tested, was of sufficient width. Those positions closest to log center gave the lowest volume yield.

Both the 3- and 6-inch minimum volume positions were significantly further from both 3- and 6-inch MOPs than were the maximum value positions. The minimum value positions were also slightly further from both MOPs than was the minimum value position, but not significantly so. Therefore, a maximum value solution distance from MOP for one log may easily be a minimum value solution for another. This result indicates that total value yield is dependent on each particular log's defect depth and orientation. To determine the value-maximizing distance from MOP for a specific log, a precise knowledge of defect location is apparently required.

For both the 3- and 6-inch MOPs, the maximum volume and centered solution positions were located closest to the MOPs. For the 6-inch MOP, this distance from MOP differed significantly from all other positions. However, for the 3-inch MOP, the centered solution position was significantly closer to the MOP than all other positions except the maximum volume position. The 3-inch MOP maximum volume position did not differ significantly from the minimum value position.

The centered solution and maximum volume solutions did not differ significantly in distance from respective MOP for either MOP. This indicates, once more, the effectiveness of the centered solution position for locating the position at which maximum volume can be sawn.

Summary

A conflict between value and volume yield was found to exist for the live sawing of hardwood sawlogs. A sawyer maximizing volume yield by employing the BOF method would lose an average of $2 per sawlog, even though volume yield would increase by about 3 board feet. Simply opening each log at the 3- and 6-inch MOPs gave the same volume yield as obtained for the maximum value position. Similarly, opening each log at random provided lumber value yields equivalent to those computed for the maximum volume position.

The minimum volume position was closest in distance to log center for both MOPs, which indicates the adequacy of the 1-inch distance across which the initial opening face positions were tested. The minimum and maximum value positions did not differ significantly in distance from MOP for either MOP tested. This result indicates that total lumber value yield is dependent on each particular log's defect depth and orientation. To obtain maximum value yield, a precise knowledge of internal defect location for each log is probably required. Thus, additional research to develop scanning devices to detect internal log defects

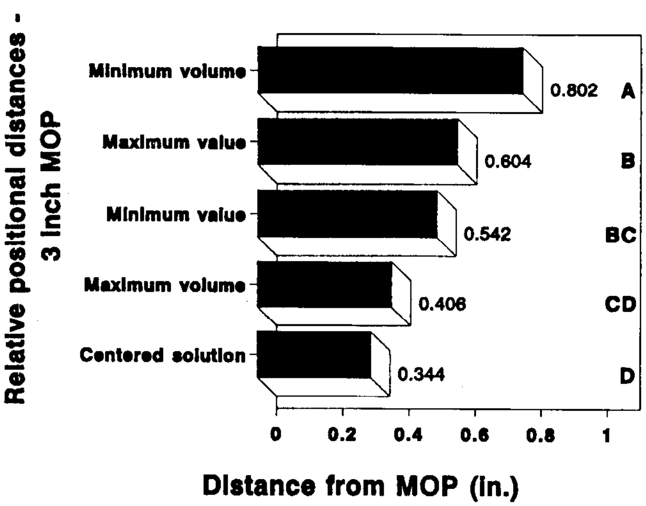

Figure 6. — Distance from 3-inch MOP by sawing position. Results of comparison-of-means tests are indicated by letters on the right side of the graph. Sawing position values with different letters differed significantly.

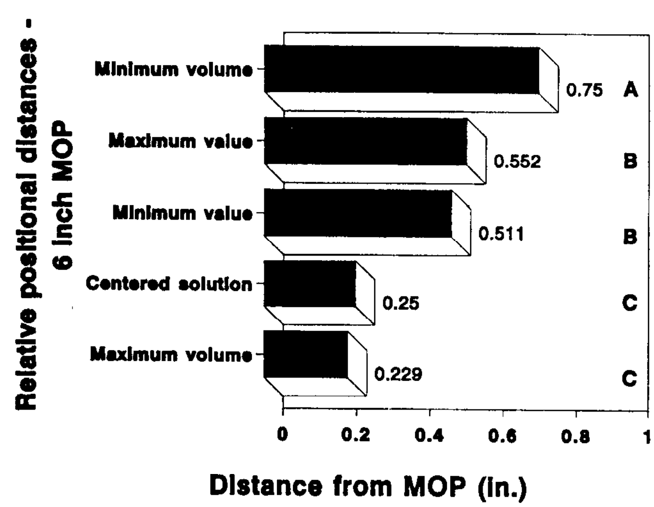

Figure 7. — Distance from 6-inch MOP by sawing position. Results of comparison-of-means tests are indicated by letters on the right side of the graph. Sawing position values with different letters differed significantly.

is required to truly maximize value yield from hardwood sawlogs.

The centered solution position was found to be a good proxy for locating the maximum volume position. The centered solution was the same distance from the MOPs as the maximum volume position. In addition, the volume and value yields for the centered solution position did not differ significantly from those for the maximum volume position.

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