INFLUENCE OF LOG LENGTH AND TAPER ON ESTIMATION OF HARDWOOD BOF POSITION

Rugeng Shi

Associate Professor
Department of Wood Science and Technology
Nanjing Forestry University, Nanjing, China

Philip H. Steele

Associate Professor
Mississippi Forest Products Utilization Laboratory
Mississippi State, MS 39762

and

Francis G. Wagner

Associate Professor
Mississippi Forest Products Utilization Laboratory
Mississippi State, MS 39762

(Received June 1988)

ABSTRACT

The influence of log length and taper on hardwood BOF position by a centered-solution method was determined. A regression equation was developed to estimate opening face position as a function of the explanatory variables: centered-solution position, difference in T2 and T1 thickness, and log length and log taper. Coefficients of these explanatory variables were significant. However, examination of sums of squares showed that the centered-solution position adequately estimated BOF position. Tests of the power of the reduced equation proved it to be accurate in estimating BOF position and that average loss in board foot yield was less than one-half percent. These results show that a single equation based on the variable centered-solution position can accurately estimate BOF position for all length and taper classes of sawlogs.

Keywords: Log length, log taper, BOF position, sawing patterns.

INTRODUCTION

Research has recently demonstrated that computation of best opening face (BOF) position for hardwood sawing can be greatly simplified. This was shown for both a symmetric sawing pattern and an asymmetric sawing pattern. For the symmetric sawing pattern, BOF position was best estimated by a centered-solution opening face position (Steele and Wengert 1987). For an asymmetric pattern, a centered-solution opening face position plus shift in direction of asymmetry was used (Steele et al. 1989). The study of asymmetric sawing patterns also showed that log diameter had insignificant influence on location of BOF position as estimated by the centered-solution method. This finding indicates that one equation can estimate BOF position for all log diameters included in a single log-length and log-taper class. This result simplifies the BOF computation process and potentially reduces computer-solution time.

Wood and Fiber Science, 22(2), 1990, pp. 142–148

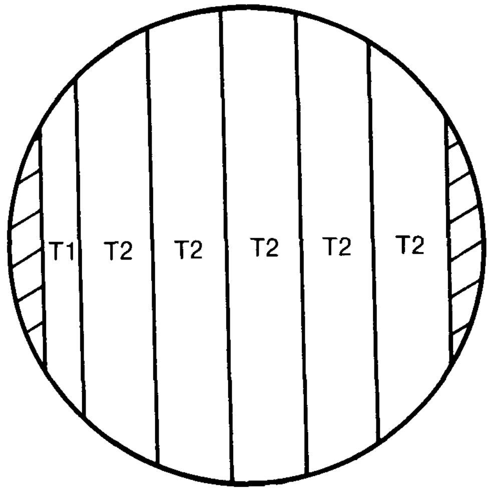

FIG. 1. Asymmetric sawing pattern produced when T1 thickness is less than T2 thickness. This was the case for seven of the eight T1 thicknesses tested in this study.

The influence that log length and taper might have on estimation of BOF position by the centered-solution method was unknown. It was hypothesized that this influence might be predicted by linear regression. If successful, this approach would further simplify BOF estimation by the centered-solution method and would allow estimation by an equation for each length and taper class. In addition, if log-length and log-taper class had no statistically significant influence on estimation of BOF position, this would mean that a single equation could estimate BOF position for all log-length and log-taper classes. This study was designed to determine, and if necessary estimate by linear regression equation, the influence of log length and taper on location of BOF position by the centered-solution method.

ANALYSIS PROCEDURES

The live-sawing model developed and described by Adkins et al. (1979), Richards et al. (1979), and as modified by Steele and Wengert (1987), simulated the hardwood sawing process for this analysis. This model tested opening face sawline position by iteratively moving it toward log center in 0.1-inch increments. The log was completely sawn at each incremental sawline tested, and board foot (BF) yields were determined. For this study, sawlines were tested at positions 0.1 inch apart across a distance equal to the thickness of the thickest dimension sawn (2.125 inches) plus kerf (0.250 inches). The total thickness was 2.375 inches, and testing of all incremental positions at 0.1-inch increments across this distance resulted in 25 sawline positions tested. The minimum lumber width produced was 3 inches at board midlength, and the minimum board length was 8 feet.

The influence of log length and log taper on BOF position for both symmetric and asymmetric sawing patterns (Figs. 1 and 2) was tested. The procedures of Steele et al. (1989) were followed. By these procedures a T1 thickness of varying dimension was sawn as the first board on the outside of each sawing pattern (Fig. 1). This T1 thickness was of lesser dimension than T2 thickness, the dimension

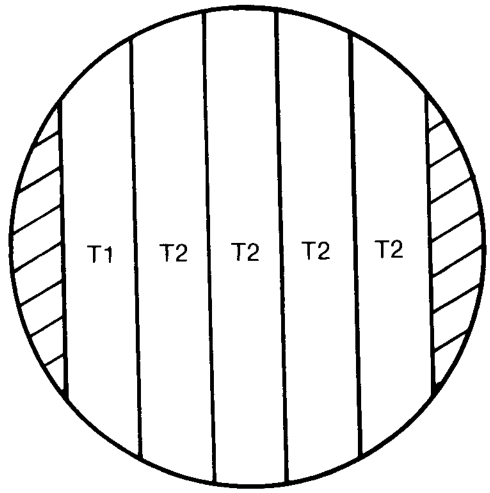

FIG. 2. Symmetric sawing pattern produced when T1 thickness is equal to T2 thickness. This was the case for only one of the eight T1 thicknesses tested in this study.

of the remaining lumber in the pattern, except in one case. For this single case a T1 thickness equal to T2 thickness yielded a symmetric pattern (Fig. 2). The T2 thickness sawn was 2.125 inches. Eight T1 thicknesses were sawn, seven of which were of lesser dimension than T2 thickness. All lumber thicknesses sawn were selected from among those defined as standard by National Hardwood Lumber Association (NHLA) grading rules (1982). All NHLA standard thicknesses up to 2 inches were used; these are shown in Table 1. Table 1 also shows that one-eighth inch was added to NHLA rough-dry dimensions to provide for shrinkage.

The log diameters used in this analysis ranged from 7.6 to 21.4 inches in 0.2-inch increments giving 70 diameters for each log-length and log-taper class. Five log-length classes (8, 10, 12, 14, and 16 feet) and five log-taper classes (0, 1, 2, 3, and 4 inches) were used. This provided 1,750 (70 × 5 × 5) logs sawn for each of the eight T1 thicknesses tested for a total of 14,000 (8 × 1,750) computer-sawn logs for the study.

BOF range is a concept defined in two previous studies (Steele and Wengert

TABLE 1. *The eight lumber thicknesses sawn in this study. These thicknesses are those given as standard rough dimensions by the National Hardwood Lumber Association (1982). One-eighth inch was added for shrinkage to all values as shown. Only standard rough thicknesses up to 2 inches were tested.*

Standard rough thickness	Standard rough thickness plus ⅛ inch for shrinkage
0.375	0.500
0.625	0.750
0.750	0.875
1.000	1.125
1.250	1.375
1.500	1.625
1.750	1.875
2.000	2.125

TABLE 2. *BF yield and distance from log center for the 25 incremental positions tested for two example logs. Maximum BF yields are bracketed. Results are for 12-foot-long logs with 1.5 inches of taper. For this example, the lumber thicknesses cut were 1.125 inch for T1 thickness and 2.125 inch for T2 thickness.*

Log diameter 15.8 inches			Log diameter 18.6 inches		
Position no.	Distance from log center (in.)	BF yield	Position no.	Distance from log center (in.)	BF yield
1	8.054	166	1	9.468	232
2	7.954	166	2	9.368	232
3	7.854	[169]*	3	9.268	[234]*
4	7.754	168*	4	9.168	[234]*
5	7.654	[169]*	5	9.068	[234]*
6	7.754	167	6	8.968	233
7	7.454	165	7	8.868	232
8	7.354	165	8	8.768	233
9	7.354	158	9	8.668	233
10	7.254	158	10	8.568	232
11	7.054	159	11	8.468	230
12	6.954	159	12	8.368	228
13	6.854	159	13	8.268	220
14	6.754	160	14	8.168	221
15	6.654	160	15	8.068	221
16	6.554	158	16	7.968	220
17	6.454	159	17	7.868	220
18	6.354	158	18	7.768	221
19	6.254	158	19	7.668	221
20	6.154	159	20	7.568	222
21	6.054	158	21	7.468	222
22	5.954	157	22	7.368	220
23	5.854	158	23	7.268	220
24	5.754	156	24	7.168	220
25	5.654	155	25	7.068	219

1987; Steele et al. 1989). BOF range is the distance, in inches from log center, across which maximum BF yield is obtained. BOF range includes incremental positions with BF yields less than maximum if these occur between maximum yields. This method serves to widen BOF range and thereby increases the chance of a practical implementation of computed BOF decisions. Past research shows that, when sawing hardwood sawlogs, negligible BF yield (0.16%) is lost as a result of widening BOF range by this method (Steele et al. 1989). These concepts are illustrated in Table 2 for two example logs where the 25 opening face positions tested for each are shown with respective BF yields. Maximum BF yields are bracketed and BOF range is indicated by asterisks to the right of BF yield values. For example, BOF range for the 15.8-inch diameter log extends from 7.654 to 7.854 inches from log center or across a distance of 0.2 inch as indicated by the range of asterisks. The maximum BF yield of 169 BF is not continuous across the range but is interrupted by a yield of 168 BF at position 4. Note that allowing BOF range to extend across this position with slightly lower yield increases the target for implementing the BOF decision from a single position to three. For the second example log of 18.6 inches diameter, maximum BF yield is 234 BF with no solutions of lower yield in the BOF range. *Mean BOF position* is the arithmetic average position within BOF range. It is the position representing the BOF position where the log would be opened to obtain maximum BF yield. For the 15.8-inch diameter log, mean BOF position is 7.754 inches from log center. For the 18.6-inch diameter log, it is 9.168 inches from log center. In this study, mean BOF position was used as the dependent variable (MNBOF) in the linear regression equation to estimate BOF position.

BF yield from use of the centered-solution position was determined by the simulated sawing of each log with the centered-solution position as the opening face position. The centered-solution position is determined by centering in the log the sawing pattern comprised of the maximum possible number of boards (Steele and Wengert 1987). The centered-solution position was used below as an explanatory variable (CEN) in the linear regression equation to estimate BOF position.

MODEL SPECIFICATION

The model measuring the influence of log length and taper is given as Eq. 1. In this formulation, a shift in direction of asymmetry is provided, following the method of Steele et al. (1989). By this method an explanatory variable (TDIF) representing the difference in T2 and T1 thickness is included to provide the required shift.

$$\text{MNBOF} = \beta_0 + \beta_1\text{CEN} + \beta_2\text{TDIF} + \beta_3\text{TPR} + \beta_4\text{LEN} \tag{1}$$

where:

β_0 = intercept term
CEN = centered-solution BOF position (inches from log center)
TDIF = difference in T2 and T1 thicknesses (inches)
TPR = log taper in 16 feet of length (inches)
LEN = log length (feet)
$\beta_1, \beta_2, \beta_3, \beta_4$ = respective explanatory variable coefficients

RESULTS

The estimated model based on Eq. 1 is given as Eq. 2.

$$\begin{aligned}\text{MNBOF} = {} & \underset{(2.88)}{0.031} + \underset{(1{,}090.97)}{0.990\text{CEN}} + \underset{(37.08)}{0.128\text{TDIF}} \\ & + \underset{(8.93)}{0.012\text{TPR}} - \underset{(5.29)}{0.0036\text{LEN}}\end{aligned} \tag{2}$$

The R^2 value for Eq. 2 was 0.989. T values[1] are shown in parentheses under variable coefficients. All variable coefficients are significant at the 0.001 level, with the exception of the intercept term, which is significant at the 0.01 level. Although all variables are significant, examination of the sums of squares (SS) explained by each shows that the variable CEN far outweighs others tested in explanatory power. CEN explained 61,149 of the total SS of 61,224 explained by

[1] T values greater than 1.96 are significant at the 0.05 level; above 2.58 at the 0.01 level; and above 3.29 at the 0.001 level.

TABLE 3. *Average percentage loss in BF yield by length and taper class from use of Eq. 3 compared to average BF yield for all positions in BOF range. Percentage losses are the average of the 70 log diameters and 8 board thicknesses tested and represent results from 560 (70 × 8) study logs.*

Length class (ft.)	Taper class (in.)					
	0	1	2	3	4	Average
8	0.589	0.654	0.651	0.613	0.606	0.623
10	0.547	0.475	0.576	0.475	0.442	0.503
12	0.479	0.427	0.432	0.479	0.443	0.453
14	0.377	0.433	0.454	0.456	0.459	0.436
16	0.329	0.492	0.446	0.503	0.391	0.432
Average	0.464	0.496	0.512	0.505	0.468	0.489

the regression. TDIF explained only 69 of total SS, TPR only 4, and LEN only 1. These results indicate that the variable CEN is a very powerful estimator of BOF position, and that the additional variables tested add little to the explanatory power of the equation. For this reason TDIF, TPR, and LEN were excluded from the equation. The equation was re-estimated and is given as Eq. 3.

$$\begin{aligned} \text{MNBOF} = \ & 0.120 \ + \ 0.990\text{CEN} \\ & (17.79) \quad (1{,}046.07) \end{aligned} \tag{3}$$

T values in parentheses beneath coefficients show both the intercept term and the variable CEN to be significant at the 0.001 level in Eq. 3 R^2 value for Eq. 3 was 0.987, compared to 0.989 for Eq. 2 with a loss in explanatory power, therefore, of only 0.002 as measured by the difference in R^2 value.

The power of Eq. 3 to estimate BOF position accurately was subsequently tested. Table 3 shows percentage BF loss from Eq. 3 compared to the average BF yield for all opening face positions in the BOF range. Each length and taper class in Table 3 represents the average percentage BF loss for 70 log diameters and 8 board thicknesses tested. Therefore, each of these values represents 560 (70 × 8) study logs. Percentage BF losses from Eq. 3, for individual length and taper classes, range from 0.329 to 0.655%. Average loss for all 14,000 logs was 0.489%. Table 4 presents the absolute distance (in inches from log center) by which Eq. 3's estimate of BOF position failed to fall within BOF range. The average miss for all 14,000 logs studied was only 0.084 inch.

TABLE 4. *Average distance by length and taper class that BOF position estimated by Eq. 3 falls outside BOF range. Averages represent results from 70 log diameters and 8 board thicknesses and represent results from 560 (70 × 8) study logs.*

Length class (ft.)	Taper class (in.)					
	0	1	2	3	4	Average
8	0.079	0.064	0.061	0.062	0.065	0.066
10	0.077	0.069	0.058	0.056	0.058	0.064
12	0.065	0.093	0.079	0.068	0.064	0.074
14	0.074	0.107	0.100	0.094	0.096	0.094
16	0.065	0.136	0.143	0.139	0.137	0.124
Average	0.072	0.094	0.088	0.084	0.084	0.084

SUMMARY

A regression equation estimated BOF position as a function of the explanatory variables: centered-solution position (CEN), difference in T2 and T1 thickness (TDIF), log taper (TPR), and log length (LEN). Coefficients of all explanatory variables were significant. Examination of sums of squares showed, however, that the variable CEN was by far the most important explanatory variable. Subsequent removal of TDIF, TPR, and LEN from the equation resulted in a negligible reduction in R^2 value from 0.989 to 0.987. A test of the power of this reduced equation showed an average BF loss of less than one-half percent for the 14,000 logs tested. Average distance by which estimated BOF position fell outside BOF range was 0.084 inch.

These results indicate that while log taper and length have significant influence on BOF position, they are not required for its accurate estimate. Use of the variable representing centered-solution alone results in an equation with explanatory power nearly equal to that of the equation that includes other tested variables. From these results it may be concluded that log length and taper may be ignored in estimating BOF position by the centered-solution method.

REFERENCES

Adkins, W. K., D. B. Richards, D. W. Lewis, and E. H. Bulgrin. 1979. Programs for computer simulation of hardwood log sawing. Res. Pap. FPL 357. USDA Forest Serv., Forest Prod. Lab., Madison, WI.

Lewis, D. W. 1985. Yield losses from sawmill scanner error. Res. Pap. FPL 459. USDA Forest Serv., Forest Prod. Lab., Madison, WI.

National Hardwood Lumber Association. 1982. Rules for the measurement and inspection of hardwood and cypress lumber. NHLA, Memphis, TN.

Richards, D. B., W. K. Adkins, H. Hallock, and E. H. Bulgrin. 1979. Simulation of hardwood log sawing. Res. Pap. FPL 355. USDA Forest Serv., Forest Prod. Lab., Madison, WI.

Steele, P. H., and E. M. Wengert. 1987. Simplified procedure for computing best opening face position. Forest Prod. J. 37(5):44–48.

———, R. Shi, and F. G. Wagner. 1989. BOF decisions for an asymmetric sawing pattern. Forest Prod. J. 39(6):15–20.