Factors Determining Lumber Recovery in Sawmilling

Philip H. Steele

Abstract

Lumber volume recovery in sawmilling is determined by a confusing interaction of several factors. The more one knows about each individual factor, the more one can understand how the factors interact. The author identifies and discusses in detail seven factors influencing lumber recovery. Past and current research is cited, and examples are given to illustrate the points made.

Keywords: Lumber recovery, sawmills, sawmilling.

Factors Determining Lumber Recovery in Sawmilling

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Introduction

Lumber recovery in sawmilling is determined by a confusing interaction of several variables. Since no two sawmills are alike, the variables that influence lumber recovery are seldom the same from one sawmill to another. This complexity confuses even those with a wide range of knowledge and experience in sawmilling.

Knowing the variables that affect lumber recovery in general can unravel the factors present in a specific mill. The purpose of this report is to identify and show how these factors operate in determining lumber recovery. The focus is on how these factors affect volume recovery. Since value recovery is often affected somewhat differently by these factors, the emphasis on volume should be noted and the points made here not taken out of context.

The Factors Identified

The following factors influence lumber recovery during the sawmilling process and are examined in detail in this report:
(1) Log diameter, length, taper, and quality.
(2) Kerf width.
(3) Sawing variation, rough green-lumber size, and size of dry-dressed lumber.
(4) Product mix.
(5) Decisionmaking by sawmill personnel.
(6) Condition and maintenance of mill equipment.
(7) Sawing method.

There are several methods for measuring lumber recovery. This report deals with two: 1) cubic volume of lumber as a percentage of total log volume, and 2) board feet of lumber from a given cubic volume of logs commonly known as lumber recovery factor (LRF). Both methods of measuring lumber recovery indicate yield but in different ways. The board foot method is based on nominal (2 by 4), rather than actual (1-1/2 by 3-1/2), thickness and width. Figures reported in this way will not, of course, be the same as those obtained from the cubic volume method. These differences are not significant in the comparisons made here and will be ignored.

The Influence of the Factors

(1) Log Diameter, Length, Taper, and Quality

Anyone familiar with sawmilling knows that large diameter logs yield more lumber per volume of input than small diameter logs. This relationship of increased lumber recovery with increased log diameter is shown in figure 1 for shortleaf pine (Clark 1970).

Although this is the expected relationship, exceptions can occur. Extremely large logs can mean advanced age and large volumes of unsound material. Since most southern pine is harvested at relatively small diameters and young age, this is seldom a factor in sawmills cutting pine. Hardwood sawmills, however, may occasionally saw older timber. If the logs from these trees contain high volumes of unsound material, the typical relationship of increased percentage of lumber recovery with increased log diameter may not hold.

Sound logs of low grade can also mean a loss of lumber recovery. I found no studies on this relationship, but reason dictates that some grading defects must be cut from the lumber to improve structural and appearance properties. The result, of course, is a loss in volume recovery.

The expected recovery-to-diameter relationship can be shown even more clearly using computer modeling (fig. 2) (adapted from Hallock et al. 1979a). With this method, all variables except diameter can be held constant while a computer simulation model of a sawmill saws the logs into lumber. No defective material exists in these computer-created logs. The computer also removes the variable of human decisionmaking involved in slabbing and edging practices.
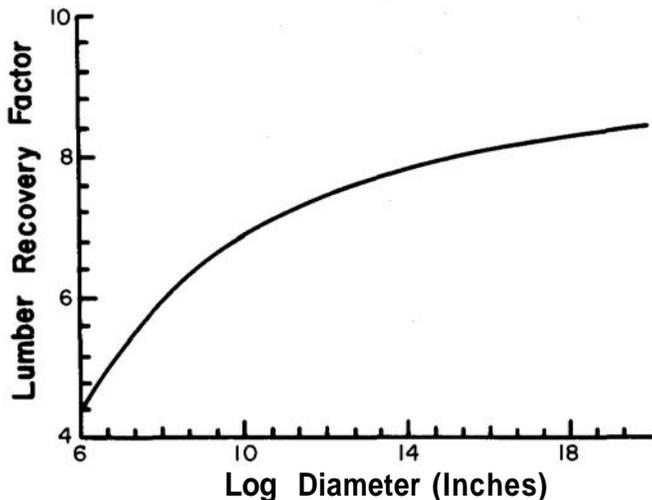
Figure 1.–Relationship of lumber recovery factor to scaling diameter for 16-foot shortleaf pine saw logs. (M151926)
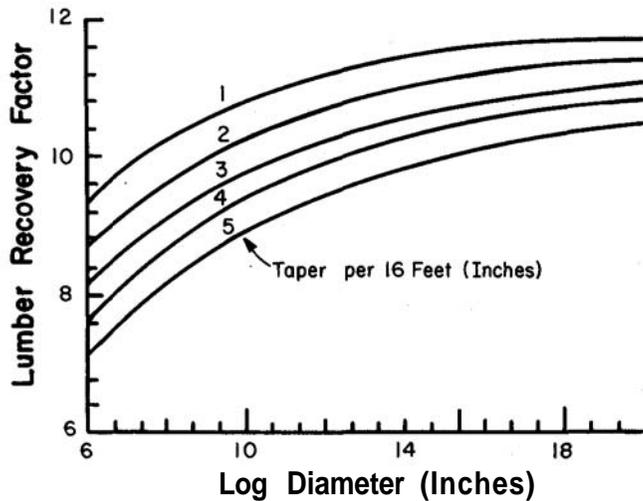
Figure 2.–Effect of log diameter and taper on lumber recovery from computer solutions. (M151849)

Taper also affects lumber recovery. The curves shown in figure 2 for each taper class are averages of values from all even-foot length classes from 8 to 24 feet using the full taper fixed fence sawing method. The higher the log taper, the lower the recovery percentage. The reason for this is that taper increases the already considerable problem a sawyer (or computer) faces in removing rectangular solids (lumber) from a truncated cone (log). The more tapered the cone, the shorter the rectangular solids that can be removed from the outside of this cone.

Taper causes a similar problem in an unexpected way when combined with log length. Log length appears to be related to lumber recovery with recovery percentage decreasing as length increases (fig. 3) (Bell 1951). Hidden in this relationship of length to recovery is the effect of taper. Log length actually has no effect on lumber recovery. Full length lumber can be removed from a zero taper log of any length with no effect on lumber recovery. When logs have taper, however, the longer the length over which this taper occurs the greater the geometry problem of sawing. The result is that more material is lost in removing taper in the slabbing and edging process, decreasing the lumber recovery percentage.

Another factor influencing lumber recovery is the interaction of actual log length as cut in the woods with the nominal log length required for lumber manufacture in the sawmill. If the length of logs from the woods is tightly controlled to allow no more than is necessary for board length, plus a minimum allowance for trim, the percentage lumber recovery from these logs will increase. No actual increase in the lumber obtained from the logs occurs. It simply takes a lesser volume of logs to produce the same volume of lumber.

This is important if the mill operator paid for a volume of material from which he has no possibility of obtaining lumber. In this case, control of the length of log entering the mill will increase lumber recovery percentage and save the operator money on log purchases as well.

(2) Kerf Width

Not long ago many sawmill operators believed that reductions in kerf width had little or no effect on lumber recovery in the sawmill. Then in 1962 a study (Hallock 1962) was conducted that showed that when kerf width was reduced from 12/32 inch to 9/32 inch, yield in board feet increased an average of 7 percent (for logs 5.5 to 12 in. in diameter).

This study proved that it is not necessary to obtain an extra board from the outside of the log as a result of accumulated kerf savings to increase lumber recovery. Without obtaining any extra boards, lumber recovery increases when a shift in the sawing pattern due to kerf reduction allows wider and longer lumber to be cut from the same log.

How does this shift work to produce wider lumber? Suppose the optimum volume solution on an 8.3-inch-diameter 16-foot-long log is 0.240 inch for a mill cutting dimension lumber (fig. 4a). If the kerf on this log is reduced to 0.180 inch, the pattern shift results in a 2 by 6 rather than a 2 by 4, with an increase in lumber yield from 64 to 69-1/3 board feet–an 8.3 percent increase (fig. 4b).
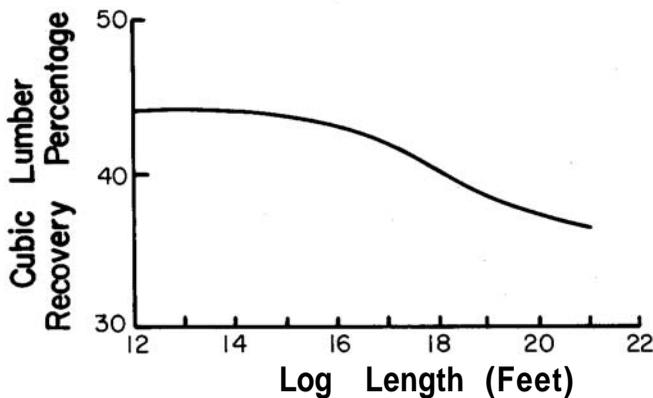
Take for example a 10.1-inch-diameter 16-foot-long log (fig. 5a). In this case a 0.060-inch kerf reduction (fig. 5b) affects lumber length rather than width. Here the two 2 by 6's on the left and right of the pattern are a full 16 feet long rather than cut back to 14 feet. The result is an increase in yield from 100 to 104 board feet–a 4 percent gain.

This is not to say that an extra board is never obtained with decreased kerf width. The greatest percentage of increased volume yield will come, however, from increased length and width of the lumber sawn.
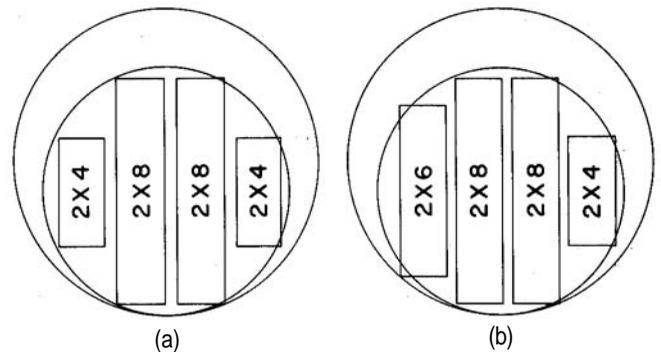
Figure 4.–Shift in pattern due to reduced kerf allows wider lumber to be cut from 8.3-inch-diameter 16-foot-long log. a) 0.240-inch kerf–64 board foot yield. b) 0.180-inch kerf–69-1/3 board foot yield. (M152041)

Figure 5.–Reduction of kerf from 0.240 to 0.180 inch allows longer lumber to be cut from a 10.1-inch-diameter 16-foot-long log. (Pieces cut to less than log length have their length indicated; those of full length show no length.) a) 0.240-inch kerf–100 board foot yield. b) 0.180-inch kerf–104 board foot yield. (M152042)

Figure 3.–Apparent effect of log length on the percentage of the log volume converted to lumber. (M151924)

3) Sawing Variation, Rough Green Lumber Size, and Size of Dry-Dressed Lumber
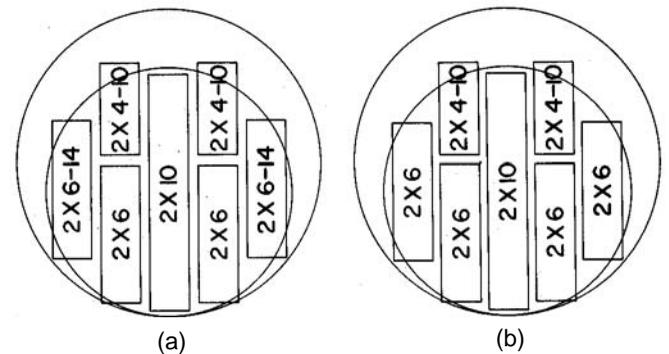
The size of rough green lumber includes allowances for the finished size of the dry-dressed lumber, planing allowance, shrinkage, and sawing variation (fig. 6). Mills often include more wood than needed for these allowances. This additional wood is known as oversizing.

Some of the allowances that make up the rough green lumber size are controllable, others are not. The finished size of the lumber, for example, is rarely controllable. Grading associations as well as the U.S. Department of Commerce have set sizing standards for various products below which the product is unacceptable and cannot be sold for the use intended. Shrinkage is another allowance that is usually fixed. Depending on the species of wood and the moisture content to which it is dried, allowance for shrinkage is a constant percentage.

Two allowances that can be controlled are sawing variation and planing allowance. Sawing variation is produced on the lumber through deviations of the sawblade itself while sawing the log, or by deviations from a straight line of the mechanisms carrying the log past the sawblade. Stress relief in the log can also contribute to sawing variation. The greater the sawing variation produced on the lumber from these causes the larger must be the allowance on the rough green piece, to assure that when planed the piece will not fall below the minimum acceptable dimension.
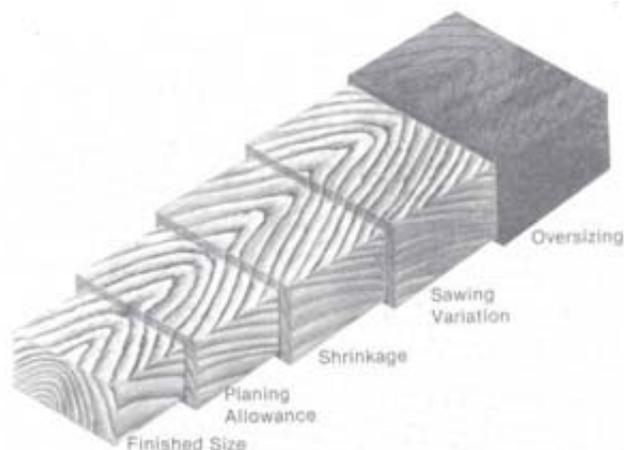

Figure 6.–Rough green lumber showing necessary allowances plus oversizing. (M146393)

How important is it to control those allowances that determine rough green target size? The answer is illustrated by an example from Stern et al. (1979). Their study used computer solutions to determine the percentage increase in recovery attainable when sawing accuracy, defined as sawing variation of two standard deviations plus oversizing, is improved. The particular example cited gives the predicted increase for improved sawing accuracy for a 1,000-board-foot sample composed of a mix of an equal number of logs from each 1-inch-diameter class from 5 to 20 inches.

Assuming that sawing accuracy on a machine with 0.125-inch kerf can be improved from 0.2 to 0.1 inch, the study shows an increase in board foot yield of 6.0 percent.

This increase is obtained in exactly the same manner described in the section on kerf width. Longer, wider pieces, as well as an occasional extra piece of lumber, can be obtained when the sawing pattern is shifted slightly by decreasing the rough green lumber size.

The allowance for planing is often excessive and can usually be reduced without adversely affecting the product. If sawing variation is reduced, so is the depth of wood that must be removed by the planer to clean the sawmarks from the piece.

Oversizing has been left out of this discussion of allowances since it isn't one. Oversizing is an extra amount over that required to satisfy the allowances already mentioned. It can simply be removed as part of the final rough green lumber size without changing the nature of the final product and with a resultant increase in lumber recovery.

(4) Product Mix

Product mix substantially affects lumber recovery in terms of cubic and/or board foot recovery. For cubic recovery, the fewer the sawlines required to remove lumber from a log, the more volume can be recovered. Therefore, all things being equal, a mill producing large dimension products will recover more cubic volume from each log.

For example, compare a mill that produces 8- by 8-1/2-inch timbers and side lumber of 1-inch actual thickness to one producing only lumber of 1-inch actual thickness. Assuming a 1/4-inch sawkerf, the timber could give seven 1-inch-thick pieces of lumber and 1-1/2 inches of sawdust when cut into 1-inch lumber with a consequent decrease in volume recovery. For a 12-foot timber, the volume lost to sawdust in this example would be 1 cubic foot. The volume of side lumber produced is assumed to be the same in both cases.

If recovery is measured in terms of board feet, the relationship shown in the previous example may change. This is because the actual thickness of lumber involved may differ from the nominal board foot credit given to it. When this is the case, certain dimensions may contain sufficient board foot scale to more than offset any extra sawlines required to produce them.

Table 1 illustrates this point for softwood lumber. Several common products produced at softwood dimension mills are shown and a comparison made of the board foot credit obtained per cubic foot of actual wood in each product. Going only by this measure (and not price), the 2 by 2 would be the best product to produce since for each cubic foot of 2 by 2's produced, credit for 21.33 board feet is obtained. This is well above its next rival, a 2 by 3, which gets credit for 19.20.

To show how kerf must be included in the calculation, a comparison of cutting two 2 by 4's versus one 2 by 8 will be examined. Assuming a kerf of 3/16 inch, it is still possible to rip a 2 by 8 in half and have 1/32 inch more than the necessary width left for each of two 2 by 4's.

Even allowing for the volume of fiber lost to kerf, two 2 by 4's in this case contain less cubic volume of wood than one 2 by 8 for the same board foot credit. Therefore, in terms of strictly board foot credit per cubic foot of fiber contained, the 2 by 4 would be the better product choice. The actual best choice is, of course, determined by the price paid for 2 by 8's versus 2 by 4's compared to the manufacturing cost of each.

The interaction of log shape and product mix further complicates recovery. The smaller the product, the easier the geometric problem of removing lumber (rectangular solids) from the outside of logs (truncated cones). The smaller the size of lumber involved, the more volume it may be possible to remove (fig. 7).
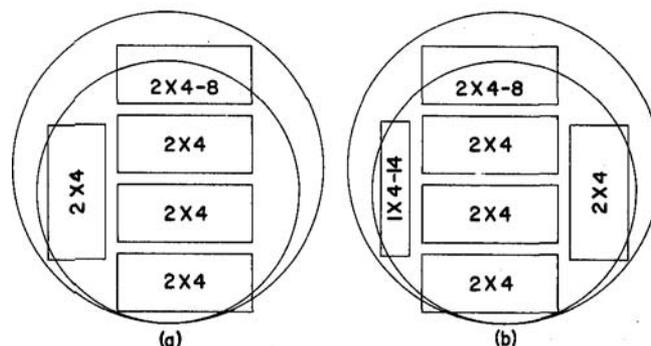

Figure 7.–Smaller dimension product allows increase in lumber recovery on a 7. 1-inch-diameter 16-foot-long log. (Pieces cut to less than full log length have their length indicated; those of full length show no length.) a) Standard dimension lumber48 board foot yield. b) Standard dimension lumber and 1 by 4's — 52 –2/3 board foot yield. (M152037)

Figure 7a shows a 7.1-inch-diameter 16-foot-long log on which the optimum volume decision has been made for a mill sawing 2-inch by 4-, 6-, 8-, 10-, and 12-inch standard dimension lumber. The same log is shown in figure 7b with the optimum volume decision if the mill recovered 1 by 4's as well. The respective board foot lumber recoveries are 48 and 52-2/3, a 9.7 percent increase.

In an actual mill situation, determining the best products to cut for maximum volume yield is not as simple as the examples shown and will require actual mill studies or computer simulation. The products that are cut, lumber-sizing practices, kerf width, sawing method, and log geometry will all influence the outcome. Such a study will be further complicated by the fact that every sawmill is interested more in value than strictly in volume recovery.

(5) Decisionmaking by Sawmill Personnel

The decisions of sawmill personnel significantly affect lumber recovery. The heterogeneous nature of the raw material demands that machine operators make thousands of decisions every day. Fatigue, lack of knowledge or ability, or carelessness can mean poor decisions. In some cases, so many variables must be considered in such a short time that even the best operator finds it impossible to make optimum decisions.

Table 1.–Relationship of board foot recovery to cubic volume for common American Lumber Standards softwood dimension lumber (12-foot length)

Nominal dimension	Actual dimension	Board feet	Volume (cubic foot)	Board feet per cubic foot
1 x 4	3/4 x 3-1/2	4	0.22	18.29
2 x 2	1-1/2 x 1-1/2	4	.19	21.33
2 x 3	1-1/2 x 2-1/2	6	.31	19.20
2 x 4	1-1/2 x 3-1/2	8	.44	18.29
2 x 6	1-1/2 x 5-1/2	12	.69	17.46
2 x 8	1-1/2 x 7-1/4	16	.91	17.66
2 x 10	1-1/2 x 9-1/4	20	1.16	17.30
2 x 12	1-1/2 x 11-1/4	24	1.41	17.07

Fortunately, recent developments in sawmilling technology enable computers to make many of these difficult decisions. The Best Opening Face (BOF) system for breaking down the log into lumber for highest recovery is one of these developments. The BOF system is based on the fact that the position of the first sawline determines the lumber recovery from the log and that proper placement of this sawline can assure optimum lumber recovery. One study of this phenomenon (Hallock and Lewis 1973) shows that a shift of only 2/10 inch on an 8-inch log for a given pattern can result in 25 percent more lumber recovery. This effect is most dramatic on small logs up to about 12 inches. For logs in the diameter range of 5 to 20 inches, this study showed an optimum face opening increased board foot lumber recovery by an average of 21 percent over the poorest face opening.

BOF increases lumber yield by shifting the pattern within the log, giving a better geometric fit of lumber (rectangular solids) inside the log (truncated cone). Figure 8 shows a poor opening face solution (8a) and two example pattern shifts of 0.1 inch (8b) and 0.2 inch (8c) with resultant increases of 13 percent and 25 percent more recovery, respectively, from an 8-inch-diameter 12-foot-long log sawn into 2-inch-dimension lumber.

Once lumber is cut from the log, a portion (30 pct or more) is in the form of flitches having wane on one or both edges. These fitches must be further edged of wane to produce manufactured lumber. Figure 9 shows a top view of two flitches with the outline of wane on both edges. Shown are two potential pieces of softwood dimension lumber edged out of identical flitches. Fifty percent more lumber volume is recovered in (9b) than in (9a) by allowing a small amount of wane on each edge but with no degrade to the piece.

A competent edger operator using good equipment can minimize losses such as illustrated in figure 9. As in log breakdown, differences in operator ability and conscientiousness, and the fact that fatigue can cause a deterioration in decisionmaking ability, have led the softwood sawmilling industry in the direction of computerizing the edging process. One user in a softwood dimension mill (Brines 1982) recovers 97 percent of theoretical optimum, an estimated 12.9 percent improvement over operator decisions.

A 1973 computer study (Richards 1973) of hardwood edging practices compared the practice of square edging lumber (leaving no wane) with that of allowing 50 percent wane extending down each board edge. This 50 percent wane allowance is that specified by NHLA hardwood-grading rules for FAS lumber. It was found that following the 50 percent wane rule yielded nearly 18 percent more lumber. The volume loss this 18 percent represents is for the most part not due to operator error but is a result of sawmill policy requiring clean edging practices.
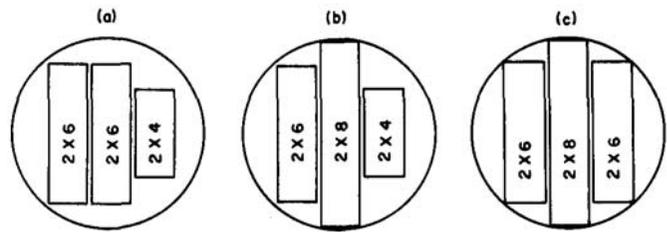

Figure 8.–Lumber recovery differences using various opening faces on an 8.0-inch- diameter 12-foot-long log. a) Poor solution–32 board foot yield. b) Better solution–36 board foot yield. c) Best solution–40 board foot yield. (M152036)
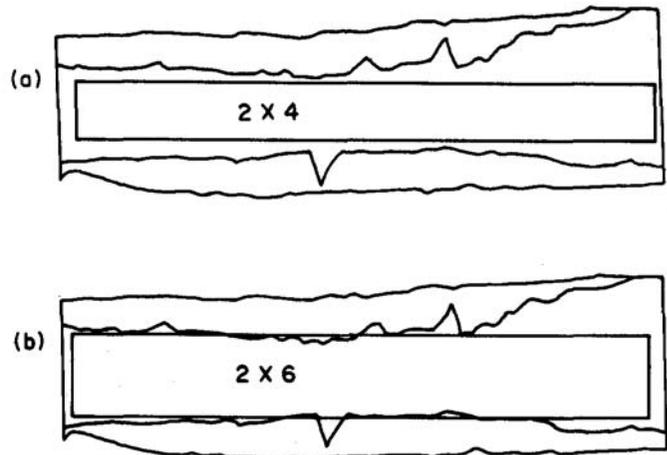

Figure 9.–Two edging solutions on the same 12-foot flitch show that allowing more wane can achieve 50 percent more volume recovery. a) Clean edging–8 board foot yield. b) Some wane allowed–12 board foot yield. (M152035)

(6) Condition and Maintenance of Mill Equipment

The condition and maintenance of equipment in the sawmill actually is the cause of other problems in the mill that have already been discussed. Equipment that is not functioning or not operated properly is the main cause of high sawing variation. Good decisionmaking in the sawmill can also be defeated if the machinery designed to carry out these decisions is inadequate to the task. An operator who can make decisions to ±1/8 inch will have his capability nullified if his equipment is only capable of ±3/16-inch accuracy.

(7) Sawing Method

Sawing method is the pattern used to break down the log into lumber. For softwood dimension mills, Hallock et al. studied sawing method thoroughly in two publications (Hallock et al. 1976, 1979b). One study (Hallock et al. 1976) addressed the subject of determining the best sawing method. To do this the various sawing methods used in softwood dimension mills were classified into eight basic patterns–six were cant sawing and two were live sawing. Cant sawing is the method of producing side lumber and cant in one plane with the cant broken down perpendicular to this first plane. Live sawing means that all sawlines are in the same plane.

The results of the study, using computer simulation, showed that a given sawing method can significantly affect lumber recovery. The best results were obtained by using a mixture of all eight sawing methods, with the best method determined by individual log geometry.

When compared against the mixture of all methods, the eight individual sawing methods ranged from 0.5 to 6.6 percent less board feet lumber recovery for the four log distributions examined. Using the best total result as the base, the six cant sawing methods examined performed a little more than 3 percent higher than the two live sawing methods.

Hallock's second publication (Hallock et al. 1979b) compared lumber yields of centered versus offset sawing. Centered sawing is the practice of sawing the log at the initial breakdown machine such that the sawlines are equidistant from the log center. Offset sawing allows a pattern shift to either the right or left (with sawlines still parallel to log center for this study) in order to increase lumber recovery using a BOF solution. The study results indicate that the probable increase in recovery should be between 5 and 10 percent in going from centered to offset sawing of logs (for a typical log diameter range of 5 to 15 in. and 8· to 16-ft length).

Hardwood sawmills generally use different sawing patterns than softwood sawmills in breaking down their logs. The most common method is the use of grade sawing, which is the practice of sawing around the log in an attempt to produce higher grade lumber from the outside of the log. There have been several studies made over the last 25 years to determine whether sawing around is indeed the optimum method of sawing hardwood logs.

Where lumber recovery is concerned, the results of these studies are mixed. Some show increased yields using live sawing, and some show no differences. None show significantly lower recovery with live sawing. These conflicting results can be explained by differences in species, grade, taper class, and length, as well as problems with adequate study control in the production sawmills in which many of the studies were carried out. At this time the evidence is inconclusive as to whether the live or grade sawing method obtains higher lumber recovery in hardwood sawmills.

The above discussions on sawing method in both softwood dimension and hardwood mills have of necessity been simplified. Sawing method is a highly complex subject with considerable ongoing research underway at present. The major point is that sawing method is an important determinant of lumber recovery in the sawmill.

Summary

The major factors that determine lumber recovery in sawmills have been identified and discussed. Though the explanations of each individual factor were simplified, they were in some cases still fairly complex. When some or all of these factors are operating in a sawmill simultaneously, a complete analysis of how lumber recovery is affected becomes extremely difficult. It is only through an understanding of the individual factors as presented here that an understanding of the final interaction can be approached.

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