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# Relative kerf and sawing variation values for some hardwood sawing machines

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# Relative kerf and sawing variation values for some hardwood sawing machines


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**Abstract**

Information on the conversion efficiency of sawing machines is important to those involved in the management, maintenance, and design of sawmills. Little information on the conversion characteristics of hardwood sawing machines has been available. This study, based on 266 studies of 6 machine types, provides an analysis of the machine characteristics of kerf width, within-board, between-board, and total sawing variations and wood loss per sawline. Machine conversion efficiency was found to be explained by feedworks and setworks type, and sawblade thickness and type. This analysis of machine characteristics provides information for a rational choice of sawing machines for hardwood sawmills.


Those involved in the management, maintenance, and design of sawmills need information on the conversion efficiency of sawing machines. Raw material costs may comprise 75 percent or more of total sawmill manufacturing costs. The choice of sawing machines that convert logs to lumber with least waste is economically important.

Some sawing machine characteristics that influence conversion efficiency are saw kerf width, sawing variation, and surface roughness. Saw kerf width determines the amount of fiber lost as each board is sawn from the log. Sawing variation and surface roughness determine the amount of wood fiber that must be added to the green thickness to assure that the final dry dressed thickness can be attained. Increased thickness of green lumber to allow for higher sawing variation and surface roughness results in higher costs for raw material as well as drying, planing, and other lumber processing costs.

For softwood sawing machines, a relative abundance of information on kerf width values (1,4,6,9,17,19) and sawing variation (2,4,5,8, 15,18, 19) is available. One publication has examined relative surface roughness of softwood sawing machines (18).

Information on the conversion characteristics of hardwood sawing machines is scarce. Only Robichaud (13) compared the characteristics of horizontal and vertical bandsaws. He reported kerf and sawing precision values for four horizontal and four vertical bandsaws and found no significant difference between the machines.

The objective of this study was to provide information about the conversion characteristics of hardwood sawing machines and to determine statistical differences between them.

## Analysis procedures

The data for this analysis were from the Sawmill Improvement Program (SIP) studies on sawing machines in hardwood sawmills. The SIP was a coopera-


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TABLE 1. – *Mean values of kerf width, within-board sawing variation, between-board sawing variation, total sawing variation, and wood loss per sawline by machine type.*

| Machine type | Machine code | No. of machines studied | Kerf width | Within-board sawing variation | Between-board sawing variation | Total sawing variation | Wood loss per sawline |
|---|---|---|---|---|---|---|---|
| Band headrig | 1 | 50 | .162 | .022 | .016 | .047 | .240 |
| Circular headrig | 2 | 168 | .282 | .026 | .015 | .054 | .371 |
| Band linebar resaw | 3 | 10 | .139 | .021 | .012 | .040 | .206 |
| Vertical band splitter resaw | 4 | 8 | .158 | .026 | .016 | .060 | .257 |
| Single arbor gang resaw | 5 | 24 | .258 | .011 | .006 | .032 | .311 |
| Double arbor gang resaw | 6 | 6 | .232 | .011 | .005 | .026 | .268 |

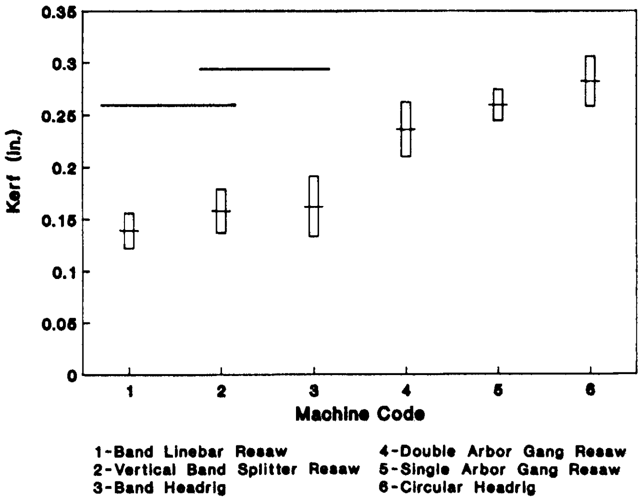


Figure 1. — Mean and ±1 standard deviation kerf width values by machine type with results of separation of means tests. Length of vertical bars indicates ±1 standard deviation about the mean. Horizontal lines indicate no significant difference between the machine types beneath them.

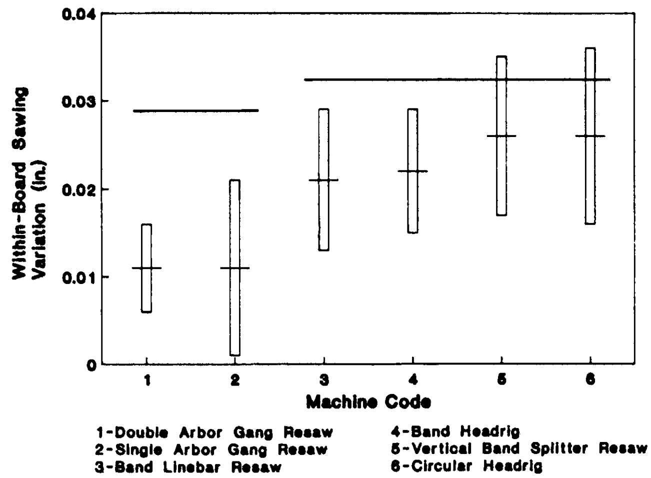


Figure 2. — Mean and ±1 standard deviation within-board sawing variation values by machine type with results of separation of means tests. Length of vertical bars indicates ±1 standard deviation about the mean. Horizontal lines indicate no significant difference between the machine types beneath them.

tive effort of the USDA Forest Service, State and Private Forestry, and state forestry organizations. At the request of a sawmill, these agencies conducted studies of conversion efficiency. SIP studies of hardwood sawmills began in 1977 and continued until 1988. These SIP studies of hardwood sawing machines represent results of 221 sawmill studies conducted on 266 individual machines in 26 states. The number of studies by machine type is given in Table 1.

The purpose of the SIP studies was to analyze sawing accuracy by machine type. The studies were made on machines of all ages under a range of maintenance regimes. An analysis of data from these studies therefore, provides information on the sawing accuracy of machines in service, rather than information on optimal performance under ideal conditions.

Kerf width was determined for each machine by randomly measuring the width of at least 10 sawteeth from each sawblade. Mean kerf width was then calculated from these 10 observations. Research on one machine type has shown that kerf width exceeds average measured sawtooth width by 7.0 percent (11). However, for the relative comparisons made in this analysis, use of an average sawtooth width was considered an adequate estimator of actual kerf width.

Determination of machine variation for a SIP study requires the measurement of 100 randomly selected boards from the production of each machine. Maximum and minimum measurements were made on each sample board. In recent years, an analysis of variance (ANOVA) method (3) of sawing variation statistical analysis has been widely employed to monitor machine performance. To make the current study values comparable to values by this method, the SIP sawing variation values were converted to values equivalent to four random measurements by the ANOVA method (3) using conversion factors developed by Peterson and Ermer (12).

SIP procedures allow the sampling of all thicknesses produced at each sawing machine. Sawing variation produced by a sawing machine should be largely independent of the thickness of lumber sawn. To increase the total sample of sawing variation values, the values for 4/4, 5/4, 6/4, and 8/4 lumber were pooled to obtain combined values for within-board, between-board, and total sawing variation for each machine type.

Data have been statistically analyzed by the least significant difference (LSD) method for comparison of means adjusted for unequal sample size (7,14). Means were considered to differ significantly if different at the 0.05 level. Results of LSD tests are shown graphically with differences in means summarized by horizontal lines at the top of the graphs (Figs. 1 to 5). For those means connected by a horizontal line, the LSD test showed no significant difference. The vertical bars in the figures indicate ±1 standard deviation from the mean value for each machine type.

## Results

### Kerf width and within-board sawing variation

Kerf width and within-board sawing variation are closely related because one cause of within-board variation is saw wander during the cutting process. A second reason for within-board sawing variation may be failure of the workpiece to be held steady by the feedworks during sawing (3). When comparing machine types, saw wander can sometimes be separated from feedworks performance when sawblade types and/or thicknesses are the same but feedworks differ. Differences in within-board sawing variation may then be assumed to be the result of feedworks performance. For machines with similar feedworks but different blade types, differences in within-board sawing variation may be attributed to blade type and/or blade thickness differences. For this method of comparison to be correct, we must also assume that no difference in saw tensioning practices between blade types have significantly influenced the sawing variation values. There is no evidence that those that tension different blade types differ significantly in skill levels. For this reason, the authors feel that this method of analysis is relatively reliable.

The majority of hardwood sawmills employ circular headrigs for log breakdown despite the fact that band headrigs have a considerably thinner kerf width. The reason for this is the ease of maintenance of inserted-tooth circular saws. A sawyer can generally maintain

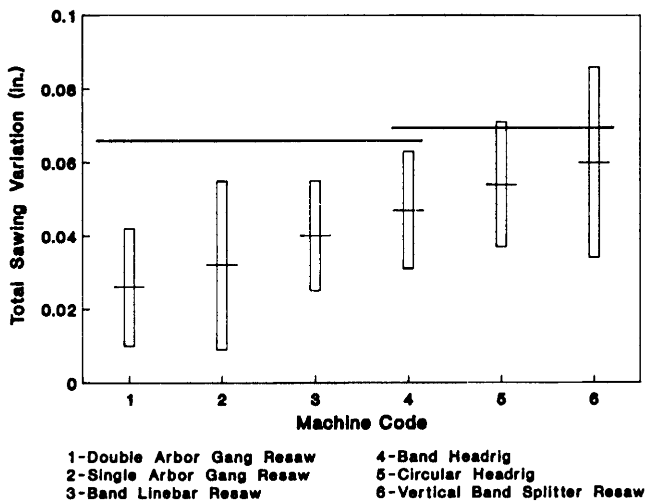


Figure 4. — Mean and ±1 standard deviation total sawing variation values by machine type with results of separation of means tests. Length of vertical bars indicates ±1 standard deviation about the mean. Horizontal lines indicate no significant difference between the machine types beneath them.

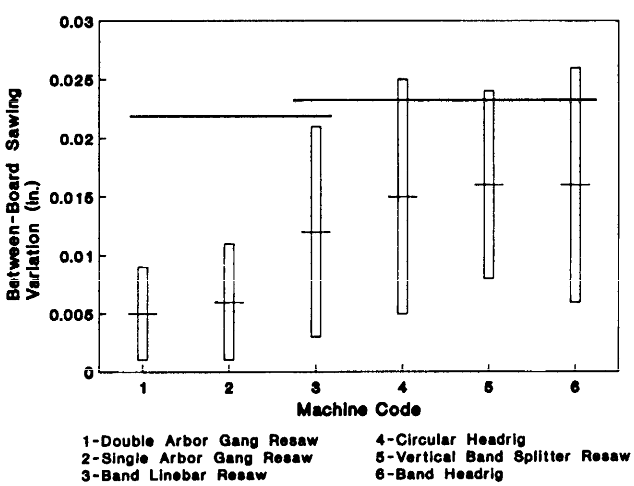


Figure 3. — Mean and ±1 standard deviation between-board sawing variation values by machine type with results of separation of means tests. Length of vertical bars indicates ±1 standard deviation about the mean. Horizontal lines indicate no significant difference between the machine types beneath them.

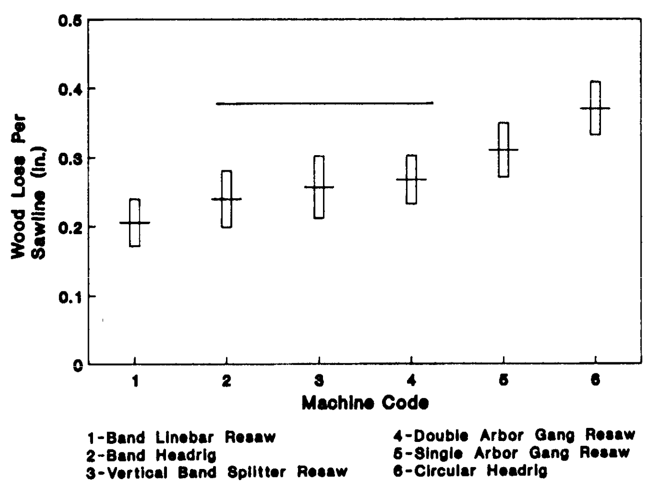


Figure 5. — Mean and ±1 standard deviation wood loss per sawline values by machine type with results of separation of means tests. Length of vertical bars indicates ±1 standard deviation about the mean. Horizontal lines indicate no significant difference between the machine types beneath them.

a circular headrig so that a tiling room or a saw filer is unnecessary. This reduces overhead cost, which is usually important due to the small size of many hardwood sawmills.

The circular headrig sawblade typically has a large diameter of 48 to 60 inches. The guidance system consists of a hardened block, usually of wood, of 1 to 1-1/2 inch diameter placed on both sides and near the outside edge of the blade. These blocks steady the blade and prevent dramatic blade wander, but the characteristics (thickness, tensioning, taper, etc.) of the blade are the main mechanical blade-stabilizing devices.

A comparison of the kerf widths for circular and band headrigs is given in Table 1 and Figure 1. The choice of a circular headrig rather than a band headrig appears a costly one in terms of wood fiber lost to sawdust in producing each board. The average circular headrig kerf width was 0.282 inch compared to 0.162 inch for band headrigs. Therefore, 0.120 inch more wood would be required to produce a board from a circular headrig compared to a band headrig. Figure 1 shows that these values were significantly different.

The thick blade of the circular headrig appears to allow sawing accuracy equivalent to the band headrig. Within-board variation is a measure of the feedworks accuracy and saw wander of the sawblade in the cut (3). Because both band and circular headrigs employ similar feedworks (carriages moved on tracks), differences in within-board variation may be assumed to result from differences in blade performance. As discussed previously, we must also assume that the saw tensioning provided to the two blade types did not significantly affect sawing variation values. The within-board sawing variation values in Table 1 and Figure 2 show that while circular headrig within-board variation (0.026 in.) was higher than that of the band headrig (0.022 in.), the values were not significantly different.

Steele et al. (15-17) have shown that some resaws in softwood sawmills have significantly different kerf width and sawing variation values. Statistical tests on the four resaw types in this study showed the same to be true for hardwood sawmills. Figure 1 shows average kerf width values for the resaws. The order from highest to lowest kerf width was: single arbor gang resaw, double arbor gang resaw, vertical band splitter resaw, and band linebar resaw. Mean kerf widths for these machines were 0.258, 0.232, 0.158, and 0.139 inch, respectively. Figure 1 shows that the means of the band linebar resaw and vertical band splitter resaw did not differ significantly. The other two resaw types differed significantly from these machine types and differed between themselves.

The double arbor gang resaw and single arbor gang resaw both had significantly higher kerf width than the two resaws with bandsaw blades (Table 1, Fig. 1). Both double and single arbor gang resaw machines employ small-diameter circular saws that generally require greater blade thickness than their bandsaw counterparts. Recent technological improvements in double and single arbor resaws, notably in the collar and guidance systems, have reduced blade thicknessso that these machines can saw with kerf widths at or near those of bandsaws. These improvements were beginning to occur during the time period of this study. However, use of extremely thin circular sawblades with pressure guides has not been reported for hardwood applications and no improved machines were in this sample. For this reason, sawing variation values for gang resaws were not influenced by differences in saw guidance systems.

The fact that the single arbor gang resaw had significantly wider kerf than the double arbor gang resaw was the converse of the finding for these resaws in softwood sawmills by Steele et al. (17). In that study, the thinner kerf widths of the single arbor gang resaws were attributed to the fact that single arbor resaws are often reserved for sawing narrower cants in softwood sawmills. Thicker cants are frequently sawn by a double arbor resaw more suited to this purpose. Because none of the hardwood sawmills in this study employed two resaws, those sawmills using single arbor gang resaws for cant breakdown would be forced to resaw all cants with this machine. while there may be other reasons, it is possible that hardwood sawmills must Increase kerf width on single arbor gang resaws above kerf widths of double arbor gang resaws because of greater cant depths sawn by their single arbor gang resaws.

As previously stated, within-board sawing variation reflects the combined result of feedworks and sawing inaccuracies (3), assuming no significant difference in saw tensioning between the machine types. While every feedworks differs and alignment of feedrolls and cant shape affect the sawing variation, the double and single arbor gang resaws have similar feedworks. Differences in within-board sawing variation between these two machines with similar feedworks are probably due to saw wander in the cut. within-board sawing variation values for the two machines did not differ significantly, which indicates equivalent blade stability. Because the single arbor gang resaws in the hardwood sawmills of this study probably sawed a wide range of cant depths, the within-board sawing variation results suggest that the thicker blades of single arbor gang resaws accomplished the task of blade stabilization required for a machine with a single blade to perform as well as a double-bladed machine.

No significant difference in kerf width was found between band linebar resaw and the vertical band splitter resaw. These two machines are essentially identical in function with the exception that their feedworks systems differ. No difference in kerf would, therefore, be expected between these machine types.

The band linebar resaw had significantly narrower kerf width than the band headrig. Steele et al. (17) indicated that resaws generally had thinner kerfs than headrigs because headrigs require a heavier blade to withstand the greater workpiece movement that occurs during sawing. Greater movement would occur on headrigs due to the mechanical difficulty of holding logs as compared to holding flat-faced cants on resaws.

The vertical band splitter resaw fell between the band linebar resaw and band headrig in kerf width and did not differ statistically from these machines.

Figure 2 shows that the sawing machines in this study fell into two groups with respect to within-board sawing variation. As previously discussed, the double arbor gang resaw and single arbor gang resaw did not differ significantly. These two machines did have significantly lower within-sawing variation than the band linebar resaw, band headrig, vertical band splitter resaw, and circular headrig. The latter four machines did not differ significantly among themselves.

Probably one factor in the comparatively accurate within-board performance of the double and single arbor gang resaws is that their kerf widths were wider than those of all other machines with the exception of the circular headrig. A second factor is that the feedworks type of these machines should also contribute to low within-board sawing variation. As Steele et al. described (15), these machines process cants on rollers with the flat cant surfaces and weight of the cants aiding in reducing movement of the workpiece with respect to the sawblade.

The three band machines (band linebar resaw, band headrig, and vertical band splitter resaw) and the circular headrig had the highest within-board sawing variation. A previous study noted the relatively high within-board sawing variation for bandsaw machine types (15). Bandsaws with high strain applied to the blades were developed in the 1970s to reduce this sawing variation. This high strain reduces saw wander during cutting, which may be a characteristic of normally strained bandsaw blades. Few, if any, of the bandsaws in the present sample employed high strain.

## Between-board sawing variation

Figure 3 and Table 1 show the results of the statistical analysis of between-board sawing variation data by machine type. Between-board sawing variation is generally a measure of the setworks functioning of a sawing machine (3).

As Figure 3 shows, the double and single arbor gang resaws had significantly lower between-board sawing variation than the circular headrig, vertical band splitter resaw, and band headrig. The band linebar resaw values were between these two groups and did not differ significantly from either group. Previous studies have shown low between-board sawing variation to be a characteristic of double and single arbor gang resaws (15). The good between-board sawing variation performance of these two machines has been attributed to their preset multiple saws (10), which virtually wlimінate the potential for the setworks malfunction or wear found on other machine types that have setworks. Likewise, the band linebar resaw may frequently saw the same thickness repeatedly without resetting the setworks. This situation should reduce error from setworks malfunction.

The circular and band headrigs employ a relatively complicated setworks with a high potential for mechanism wear and malfunction. The complicated setworks mechanism is necessary to position the log on the carriage. The higher between-board sawing variation of these machines was as expected.

The vertical band splitter resaw, as its name implies, splits doubles and quads (cants with either two or four boards to be resawn). In this operation, errors in sizing the double or quad cants that have been produced at other machines are simply divided evenly between the halves of the split cant. With this potential source of between-board sawing variation from other machines added to that actually produced at the vertical band splitter, the relatively high between-board sawing variation value for this machine type was not surprising.

## Total sawing variation

Total sawing variation is a function of within- and between-board sawing variation (3). Accordingly, the three machines that rank lowest for total sawing variation were those that had lowest combined within- and between-board sawing variation. These three machines were the double arbor gang resaw, the single arbor gang resaw, and the band linebar resaw. The total sawing variations of these three machines were not significantly different from each other or from the band headrig.

Two of the three machines with lowest total sawing variation were those that employed small-diameter circular saws and that fed a flat-faced cant past preset saws. A previous study found that this combination of features produced low variation on softwood sawing machines (15). The relatively wide blades of these two machines also may have reduced within-board sawing variation by stabilizing the blade during cutting.

The machine with the third lowest total sawing variation is the band linebar resaw. This machine shows some of the characteristics of the double and single arbor gang resaws. A flat-faced cant is processed and, as has been observed, the setworks may not be reset for long periods of time. This lack of setworks movement should, like the preset saws of the double and single arbor gang resaws, reduce the potential for between-board sawing variation.

The two machines with highest total sawing variation were the circular headrig and vertical band splitter resaw. These machines did not differ significantly from each other and did not have any features in common except consistently high within- and between-board sawing variation.

## Wood loss per sawline

An important sawing machine characteristic is the total wood fiber lost during the production of each piece of lumber. This value has been termed wood loss per sawline by Steele et al. ( 16), who showed that the machines with the lowest kerf width were not always those that removed the least wood. Reduced kerf width sometimes increases total sawing variation and increases the amount of wood that must be planed away to produce properly sized lumber. The value of wood loss per sawline is the sum of kerf width and the value derived from multiplying 1.645 times total sawing variation as described by Brown (3).

Wood loss per sawline values for the six machines are given in Table 1. Figure 5 shows the results of the separation of means by the LSD method. The band linebar resaw, with a wood loss per sawline of 0.206 inch, had the significantly lowest wood loss per sawline of all machine types. This machine had the lowest kerf width, but was third highest in total sawing variation. The fact that this machine had higher total sawing variation did not cancel the advantage in low wood loss per sawline it gained from narrow kerf width. The band linebar resaw is an outstanding performer in terms of wood loss per sawline and is more than 1/32 inch (0.034 in.) lower in this measure than the machine with the next highest value. The band headrig, vertical band splitter resaw, and double arbor gang resaw were not significantly different from each other in wood loss per sawline, with values of 0.240, 0.257, and 0.268 inch, respectively. Here again, we seethe advantage that the lower kerf of bandsaws provide in minimizing wood loss per sawline. The relatively high total sawing variation values for the vertical band splitter resaw and the band headrig were largely compensated for by low kerf width and therefore these machines performed with moderate wood loss per sawline.

The single arbor gang resaw had the significantly highest wood loss per sawline of all machine types except the circular headrig. Heavy kerf width was the primary factor differentiating the single arbor gang resaw from the double arbor gang resaw. The single arbor had significantly wider (0.023 in.) kerf than the double arbor. The single arbor gang resaw was slightly higher in total sawing variation (0.006 in.), but did not differ significantly. These relative values indicate that the choice of single over double arbor gang resaw for cant breakdown may be costly In wood loss. Well over 1/32 inch (0.043 in.) more wood fiber is required per board produced.

The combined factors of significantly highest kerf width and relatively high total sawing variation caused the circular headrig to have the significantly highest wood loss per sawline (0.37 1 in.). The circular headrig required 0.131 inch more wood fiber per sawline than the band headrig, a machine that performs the same log breakdown functions. These relative values indicate that the choice between the circular headrig, which is easier to maintain, and the band headrig, which has higher maintenance costs, should be considered carefully by hardwood sawmiller.

### Summary

The circular headrig, with its need for a stiff sawblade for stabilization, had the significantly highest kerf width of all machine types. Compared to the band headrig, the circular headrig had a 0.120-inch wider kerf. Equivalent within-board sawing variation values showed that the very different blade types of these two machines have equivalent stability.

The double and single arbor gang resaws had the significantly highest kerf width of the resaws. Bandsaw blades in resaws have much narrower kerf widths compared to those of small-diameter circular sawblade machines. The higher kerf width for the single arbor gang resaw, compared to the double arbor, was attributed to the need for the single arbor to saw deeper cuts.

Within-board sawing variation was equivalent for double and single arbor gang resaws, which indicates that the increased kerf width of the single arbor gang stabilized the sawblade in deeper cuts. The significantly superior within-board sawing variation performance of the double and single arbor gang resaws was attributed to their heavy kerf width and feedworks type. Feedworks that process flat-faced cants on rollers have also been shown to perform best in softwood sawmill studies. Machines with bandsaw blades were in the group with the significantly highest within-board sawing variation. This is a characteristic of bandsaws without high strain.

Between-board sawing variation was low for the double and single arbor gang resaws, presumably due to their preset saws. The band linebar resaw also showed good between-board sawing variation performance because this machine's setworks are often not reset between subsequent cuts. The vertical band splitter resaw inherits between-board variation from other machines and adds its own variation to become the machine with the second highest between-board sawing variation.

The sawing machines with the lowest total sawing variation were those that employed small-diameter circular saws with relatively heavy kerf width and that fed a flat-faced cant past preset saws.

Due to its low kerf width, the band linebar resaw performed significantly best in terms of wood loss per sawline. Narrow kerf width enabled bandsaw machines, both headrigs and resaws, to saw with relatively low wood loss per sawline. The heavy kerf widths apparently required to stabilize the circular headrig and single arbor gang resaw caused these machines to have the significantly highest wood loss per sawline.

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