Forintek Canada Corp.

Forintek Canada Corp.
Eastern Division
319, rue Franquet
Sainte-Foy, QC
G1P 4R4

Project No. 2404

Performance Evaluation Guide for Optimized Log Breakdown Equipment

by

Pierre Bédard - Jean McDonald
Scientists
Lumber manufacturing Technology

May 2003

Forintek Canada wishes to thank its industry members, Natural Resources Canada (Canadian Forest Service), and the Provinces of British Columbia, Alberta, Saskatchewan, Quebec, Nova Scotia, New Brunswick, and Newfoundland & Labrador for their guidance and financial support for this research.

Project Leader | Project leader | Reviewed by | Department manager

Notice

This is an internal document of Forintek Canada Corp. (Forintek), which cannot be distributed without permission from Forintek. Distribution of this document does not constitute publication, and it shall not be copied or distributed to individuals or parties other than those intended by Forintek. In addition, this report shall not be quoted, in whole or in part, without Forintek's prior permission.

Neither Forintek Canada Corp. nor its members nor any other person acting in their names may offer guarantees, explicit or implicit, or assume any legal liability as to the completeness of the information, equipment or products used, or affirm that the use of the information disclosed does not contravene any private rights. Any mention in this report of commercial products, processes or brand names, manufacturers or others shall not be construed as approval by Forintek or any of its members.

Foreword

This guide proposes a method to evaluate the performance of optimized log and cant breakdown equipment as a tool for mill personnel to improve production efficiency. Optimized systems are found in all aspects of modern sawmills, and evaluating their ability to maximize product value is not necessarily a simple task..

Analytical methods presented in this guide are primarily intended for sawmill technical staff, i.e. technicians and engineers responsible for process improvement. With this guide and a better understanding of optimizers' operating mode, they will be in position to implement a control method based on the efficiency of the log breakdown equipment

To be successful, a performance evaluation test needs to be properly planned. Once objectives have been clearly defined, a methodology must be laid out for the results to be significant and conclusive. Forintek specialists are available at all times to help a company set up a project of this nature.

Acknowledgements

Forintek wishes to acknowledge several member companies, including Tembec, Bois Daaquam, Comact and Sawquip International, for their critical contributions to this project's implementation. The mills and log breakdown equipment they made available to us played a key role in the development of the evaluation methods proposed in this guide.

Table of Contents

List of Tables

List of Figures

1 Objective

The objective of this study was to provide sawmill operators with analytical methods to evaluate the performance of optimized log and cant breakdown equipment.

2 Introduction

In the log breakdown operation, saws or chipper knives convert the entire log into a two-sided cant, which a bull edger subsequently turns into a series of cuttings. The operation is described as optimized because 1) it is essentially automated, and 2) the selection of a sawing pattern and the positioning of the log or cant with respect to cutting tools are determined by a computer-based system designed to maximize volume recovery, or, more frequently, value recovery in the resulting products.

An optimized breakdown system consists of three main components: a vision apparatus (scanner) generating numerical images of the geometric profile of the logs or cants to be sawn; a computer system to process scanner data and calculate optimum sawing solutions on the basis of user-defined criteria (e.g., product specifications, selling prices, saw kerf, etc.); and finally an automated mechanical system ensuring that the optimum solution may be produced; the positioning system controls cutting tools as well as the mechanical parts responsible with positioning the wood.

The performance of the overall optimized system is conditional on the performance of individual components, and, as in a chain, it can only be as good as that of its weakest link. In this case, if the scanner is off by half an inch, the optimization system cannot be expected to work miracles, even though all other components may be doing the best possible job. Consequently, an optimizer's evaluation requires that individual components be assessed individually, which involves the scanner (the "eyes" of the system), the computer program (the "brains"), and the positioning system (the "arm").

Evaluation methods detailed in this guide are intended to quantify the system's efficiency, i.e. the ability of the log or cant breakdown system to maximize volume or value recovery. Forintek personnel developed these methods over the years as they analyzed process efficiency in a variety of member mills. The information communicated by this guide is the product of Forintek's experience, and analytical methods will continue to evolve in coming years.

3 Personnel

Pierre Bédard	Scientist, Lumber Manufacturing Processes
Jean McDonald	Scientist, Lumber Manufacturing Processes
Francis Fournier	Scientist, Lumber Manufacturing Processes
Yves Giroux	Technologist, Lumber Manufacturing Processes
Ghislain Veilleux	Technologist, Lumber Manufacturing Processes

4 Description of Optimized Breakdown System

Let us begin with a description of a typical optimized breakdown system in a softwood mill. The diagram in Figure 1 shows all the elements of the log and cant breakdown process. Following the debarking operation, the logs are usually sorted in diameter classes or according to sawing patterns in accumulation bins. It is not unusual in modern mills, however, to observe logs of random diameters being sawn without prior sorting (*scan and set* mode). Whether the logs are sorted or not, the optimization process begins with log measurement by a scanner; this may be a true shape scanner (3D) or a shadow scanner (2 axes). Measurements are fed into the computer program, which selects a sawing solution, i.e. a sawing pattern. The optimizer also controls the log turner, the feed chain, and the canter twin, which carry out the primary breakdown operation.

Secondary sawing, edging, and trimming operations are performed in the same manner. A scanner measures cant profiles, the computer program analyzes the information and determines the best sawing solution, and instructions are transferred to the feed deck, where the cant is positioned as required for sawing by the bull edger. A board scanner measures sideboards from the primary breakdown, as well as reman boards from the trimmer. A third optimizer calculates optimum edging solutions for the edger. Finally, all cuttings from the production line run through a board scanner used to determine optimum trimming solutions for a multiple-saw trimmer.

The purpose of this study is to develop a method to quantify the rate of efficiency of primary and secondary breakdown operations so that they may be optimized for value recovery. It should be noted that Forintek has published similar guides to evaluate the performance of optimized edgers and trimmers.

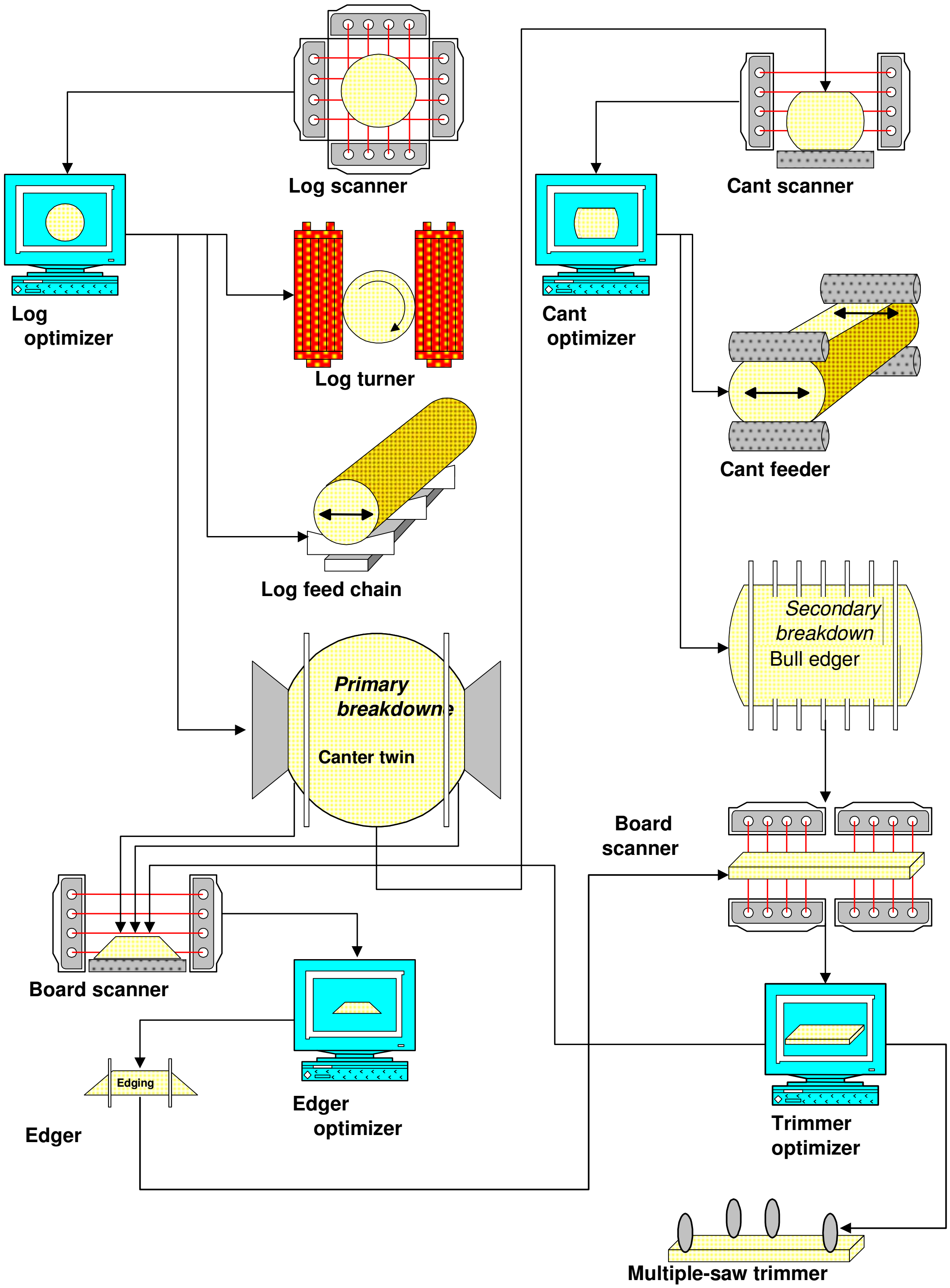


Figure 1. Schematic view of optimized breakdown process

5 Scanner Evaluation

5.1 Scanner Calibration

The optimization process begins with wood measurement by a scanner. All scanners should normally be calibrated on a regular basis as specified by the manufacturer of the equipment. We recommend weekly calibrations, particularly with systems using optical cameras (3D scanners) as they are sensitive to ambient light and likely to provide unreliable readings if lighting conditions vary. Scanners should be calibrated immediately prior to any performance evaluation test.

Once a scanner has been calibrated, it should be verified with PVC (or steel) pipes of at least two different diameters. Ideally, you should use a pipe of about 4 inches in diameter for the smaller size, and a larger one selected according to your log supply (e.g., 8 inches). The pipes need to be as round as possible (out-of-roundness should not exceed 0.1 inch) and long enough to fit on the feed chains. Il may be necessary to paint the pipes in a beige colour with a flat finish to test 3D scanners.

Run each pipe through the scanner at least three times to verify that readings are repeatable. Table 1 provides an example of readings obtained with 4-inch and 8-inch diameter PVC pipes. A brief analysis of the results shows that the scanner is accurate to within 0.1 inch, with a tendency to over-evaluate diameters, as maximum deviations are positive in both cases. This is not a bad result, but a slightly positive bias can be expected. You can run the test a second time for greater confidence. If the average deviation over three tests exceeds ± 0.2 inch, calibration of the scanner should be repeated. If the maximum upper deviation exceeds 0.3 inch, caution is also warranted; re-calibrate if at all possible, and repeat the test.

Table 1. Scanner calibration verification with PVC pipes

Average diameter	1st pass	2nd pass	3rd pass	Average	Ave. deviation	Max. deviation
4-inch pipe	4.2	4.0	4.1	4.1	+ 0.1	+ 0.2
8-inch pipe	8.1	8.3	7.8	8.1	+ 0.1	+ 0.3

With this method, you can check if the scanner is operating properly, but you still do not know how precise its readings are. Shadow (x,y) scanners are usually designed for a resolution of 0.10 inch, or, at best, 0.0625 inch; this is the space between two successive light beams, which determines the system's resolution. In systems using optical cameras (3D) the resolution specified by the manufacturer may be much finer, hence readings can be much more precise. The following section provides a more sophisticated method for use with systems capable of greater precision.

5.2 Precision of 3D Optical Scanners

To quantify the precision of a 3D scanner, either to control guaranteed performance or simply to evaluate system performance at some point in time, you will need a reference steel or aluminium tube whose diameter has been machined to at least double the precision level specified for the scanner, i.e. approximately ±0.010 inch. The pipe should be long enough (ideally, 8 to 10 feet) to be supported by the feed chains. The diameter of the pipe should also be representative of the log supply to the mill.

You need a minimum of 30 measurements along the length of the pipe, which you obtain by moving the pipe longitudinally through the scanner. Whenever possible, scan the pipe in the dynamic mode, collecting data throughout the length of the pipe.

Figure 2 illustrates the profile of a 4.50-inch steel pipe measured with a 3D scanner. Diameters were measured at one-inch intervals along the full length of the calibration pipe. Diameters in the x and y (horizontal and vertical) directions were also obtained by means of Optitek, and the corresponding values were transferred to Table 2 for statistical analysis. Figure 3 displays the histogram of the readings in the x and y directions.

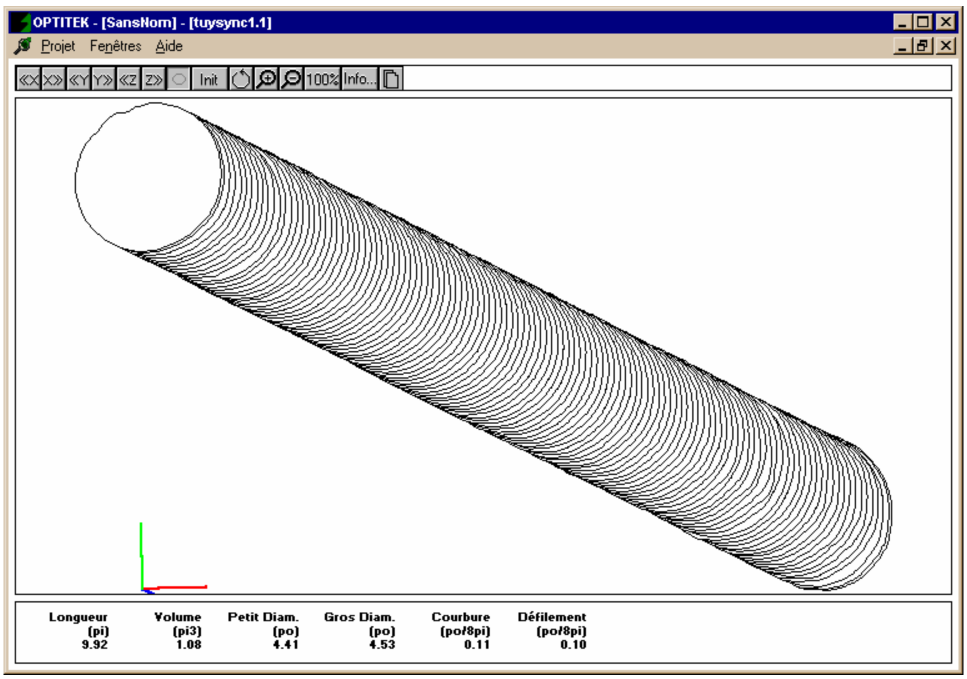


Figure 2. Optitek representation of scanned steel calibration tube profiles

Table 2 provides a series of statistical indicators of the scanner's precision. The median is an excellent indicator of overall scanner precision. Along the y axis, the reading corresponds to the exact diameter of the pipe; along the x axis, however, there is a deviation of – 0.020 inch between readings and actual diameters, i.e. underestimation of diameters. As the standard deviation is comparable along the two axis, the deviation can be said to be constant. In other words, the test reveals a degree of out-of-roundness (0.020 po), which causes diameters in the x direction to be slightly undervalued. Precision remains excellent despite reading deviations (minimum and maximum values) as high as ± 0.060 inch against the median.

This analysis describes a model that can be used to evaluate the precision of a 3D scanner, but the criteria used to define acceptable precision must be agreed on by mill operators and equipment manufacturers at the time the scanner is purchased. Periodic controls of existing scanners can be implemented to ensure that acceptable precision levels are maintained.

Table 2. Statistical analysis of scanner measurements for calibration pipe

Statistics	x axis diameter	y axis diameter
Average	4.478	4.497
Median	4.480	4.500
Mode	4.463	4.511
Standard deviation	0.019	0.022
Skewness coefficient	-0.405	-0.559
Range	0.118	0.136
Minimum	4.408	4.417
Maximum	4.526	4.553
Number of specimens	116	116

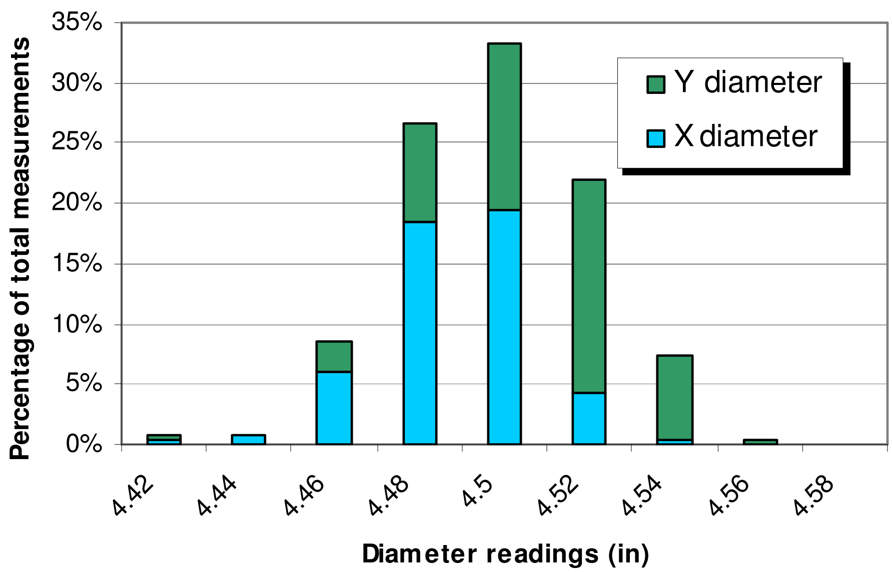


Figure 3. Histogram of scanner readings

6 Evaluation of Log Positioning

Log positioning is achieved through a combination of rotation and translation displacements prior to the primary breakdown operation. A log turner causes the log to rotate around its longitudinal axis, while displacement perpendicular to the longitudinal axis (translation) is performed by the infeed module or the feed chain. Most log feed systems can achieve a translation. Some systems are equipped with a sharp chain and self-centring rolls, in which case the chain and hold-down rolls seek to centre the log with respect to the breakdown equipment and maintain it in that position until it is processed. With some systems, however, the cutting tools can be off-centred with respect to the feed axis, which achieves the same results.

6.1 Evaluation of Log Rotation and Centring

In a test intended to evaluate log rotation and centring efficiency, it is desirable to set the optimizer so the positioning system always places log sweep into a vertical position and controls cant centre in the logs. Otherwise, the values selected by the optimizer will need to be derived from the values measured off the logs.

6.1.1 Sampling

The positioning test should be based on a sample of logs representative of the mill's regular wood supply with respect to diameters and lengths. The sample should consist of a minimum of 30 logs, but we recommend increasing this to 50, particularly if log characteristics and diameters are significantly variable. Select the logs at random, but avoid “abnormal” cases such as broken or split logs. Also avoid heavily rotten logs, as end sections may prove difficult to mark and identify. Trim off angled logging cuts to obtain clean cuts perpendicular to longitudinal log axis. Given that the centring operation is based on the thin end of the log, logs with significant multi-directional crooks at the thin end must also be discarded. As a final recommendation, you will find the evaluation test easier to perform if you select logs with regular geometries at both ends.

6.1.2 Equipment Required

- Spray paint,
- Marking template (made from an 8½ x 11 sheet of hardboard, ¼-inch thick, with a vertical arrow cut into it with a portable circular saw),
- Marking pens or numbered plastic tags,
- Digital camera with minimum 2x optical zoom
- Steel ruler and protractor

6.1.3 Log Marking and Identification

Mark reference lines on log end sections before the positioning test (Figure 4). Use the template with the arrow cut-out to indicate sweep orientation, and draw the arrow through the geometric centre of the log end. To determine the orientation of vertical curvature, two operators placed at both ends of the log may rotate it until the back (i.e. the concave portion) is on top. This method based on human judgment usually yields excellent results. If decisions need to be validated, you can also stretch a wire between the two ends, measure maximum deflection at that position, and repeat this operation at different positions until the greatest deflection indicates the vertical sweep.

To facilitate traceability, we apply a numbered tag at the small end, but it is normally more advisable to write identification numbers directly on to log end sections with a marker if the cut surface is sufficiently smooth.

Figure 4. Log marking

6.1.4 Log Breakdown

Once you have marked and identified your test logs, you may proceed with the breakdown operation. You should preferably cut the test logs outside regular working hours, as they need to be cut one at a time. You can analyze the results straight off the cants if they can be taken off the production line, but it is usually safer to analyze results from digital photographs. In this case, you only need to stop the cant on the outfeed table long enough to record its identification number and take a picture. Figure 5 shows a cant being photographed as it comes out of the primary breakdown equipment (canter twin). With a digital camera, you have time to make sure that every photograph is sufficiently clear to show the number and the arrow before you move on to the next log and the rest of the breakdown operation. By using a camera with a zoom lens, you can take pictures while staying at a safe distance from conveyors. Sawing results are analyzed directly from prints of the photographs.

6.1.5 Results Analysis

To analyze the results of a positioning test, you first print out the digital photographs representing all your cants. By tracing reference lines, you can measure rotation and centring errors (see Figure 5). Rotation errors are measured with a protractor: first draw a line parallel to the cant's faces and running through the centre; then draw a second line parallel to the arrow indicating the vertical curvature of the original log. To determine centring errors, measure distance differentials between the centre and the respective cant faces. You can measure distances directly on the print, and then extrapolate to the actual thickness of the cant, as shown in the following example:

$$\text{Offset} = [(17 - 19) / (17 + 19)] / 2 \times 5.875 \text{ in} = -0.0278 \times 5.875 \text{ in} = -0.163 \text{ in}$$

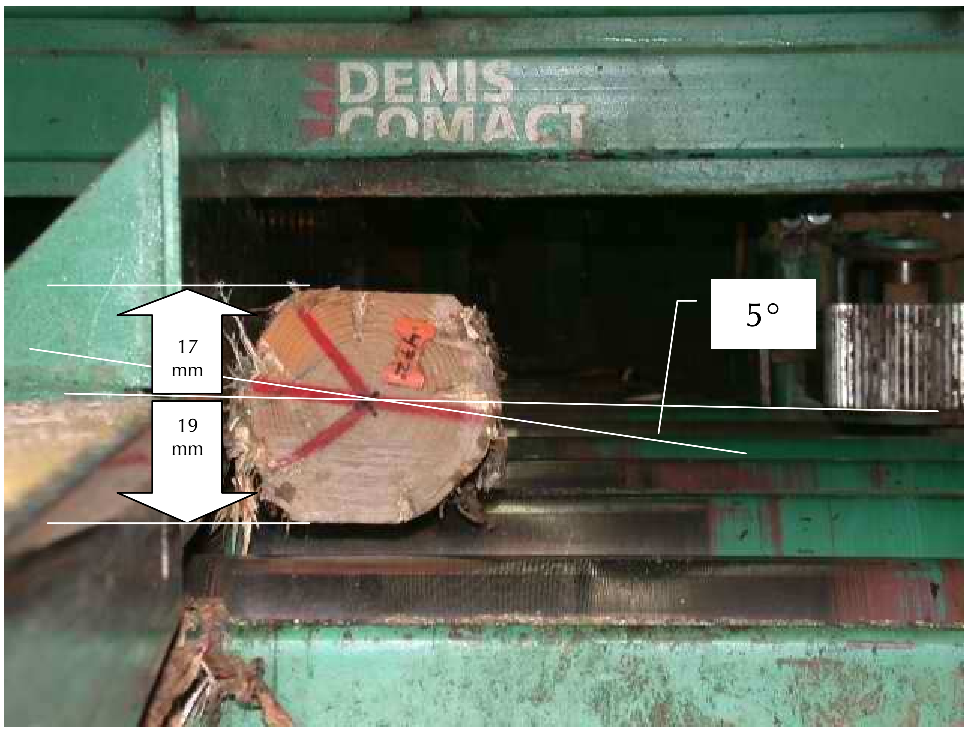


Figure 5. Cant photographed immediately after primary breakdown

The next step is to compile all your test results into a table. The statistical indicators applicable to rotation and centring errors must be calculated on the basis of measurements obtained from the sample. Table 3 illustrates a format that can be used to compile results from the log positioning test.

Table 3. Compilation of positioning errors

Log number	Rotation error (°)	Distance to top face (mm)	Distance to bottom face (mm)	Centring error (in)
401	0	21	21	0.00
402	6	20	22	0.14
403	1	8	21	0.84
472	5	17	19	0.16

For an exhaustive analysis, you can also generate descriptive statistics and a histogram. The statistics shown in Table 4 provide specific information on log-turner accuracy, and the histogram in Figure 6 illustrates the distribution of rotation errors; both sets of results are based on samples of 65 logs. For these two samples, the average rotation error tended to be around 23°, but errors peaked to as much as 90° in approximately 5% of the logs. Please, note that there is a critical difference between error average (in absolute value) and average rotation. Average rotation is likely to be close to zero, as positive and negative errors tend to cancel each other out. On the other hand, the error average refers to the average rotation error (positive or negative) attributable to the log turner.

Table 4. Descriptive statistics for rotation errors measured on two different production lines

Statistical indicators	Line 1	Line 2
Error average (absolute values)	22.8	23.4
Average rotation	4.7	-0.3
Median	2.5	0
Mode	-1	0
Standard deviation	31.5	33.1
Skewness coefficient	-0.3	0.8
Range	167	154
Minimum	-86	-65
Maximum	81	89
Number of specimens	32	33

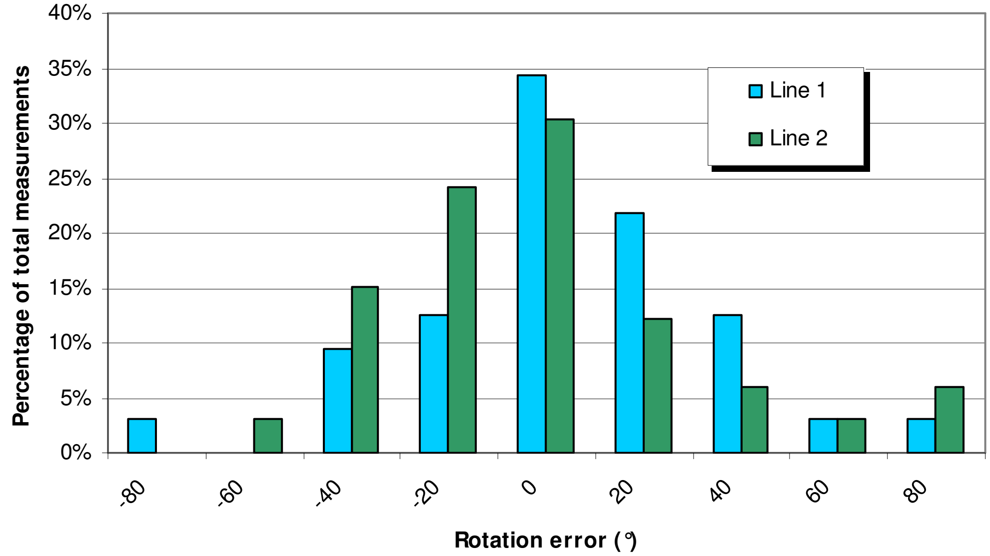


Figure 6. Histogram of rotation errors

To better visualize the results, you can also generate descriptive statistics (Table 5) to quantify centring accuracy, and develop an histogram illustrating error distribution (Figure 7). Average centring is close to zero, but centring errors average close to ¼ inch. The standard deviation on centring errors reveals rather substantial variations in log centring efficiency. It should be kept in mind, however, that rotation and centring are interrelated and can hardly be dissociated. If centring precision could be measured in the absence of rotation errors, the results would most likely be much better.

Table 5. Descriptive statistics for centring errors measured on two different production lines

Statistical indicators	Line 1	Line 2
Error average (absolute values)	0.238	0.227
Average centring	0.080	0.000
Median	0.07	0
Mode	0	0
Standard deviation	0.307	0.330
Skewness coefficient	0.0	-0.5
Range	1.36	1.89
Minimum	-0.52	-1.09
Maximum	0.84	0.80
Number of specimens	32	33

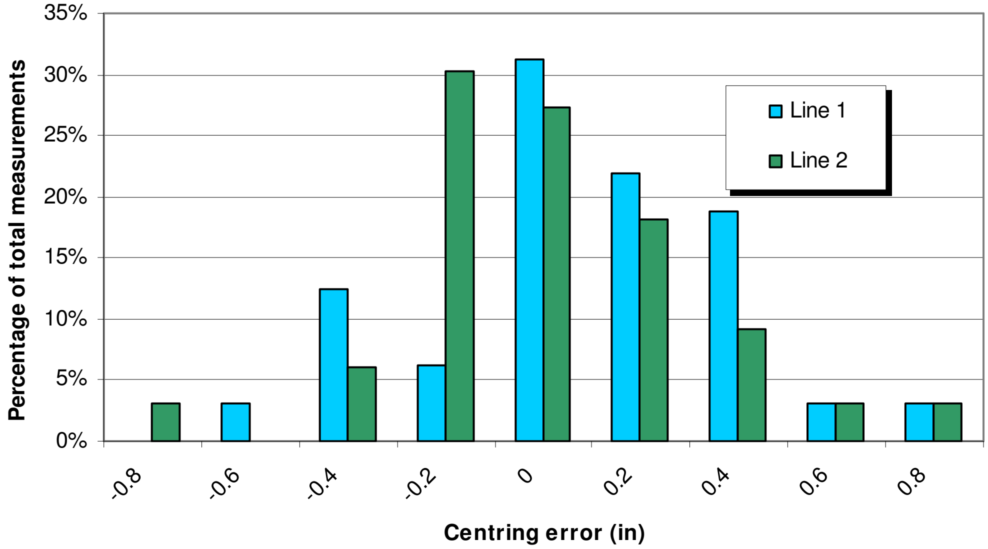


Figure 7. Histogram of centring error

7 Evaluation of Cant Positioning

The systems used to optimize the secondary breakdown of cants by a bull edger are of two types: transverse or linear. They differ in the way the scanners measure and position the cants. In a transverse system, cants stop for positioning, while, with the linear system, positioning is achieved in the dynamic mode. The main benefit of a linear system is that the breakdown process is continuous, more fluid, and more ergonomic. On the other hand, a transverse scanner operates at a lower speed, which may allow for more accurate measurements.

Whatever the equipment used, cant positioning consists of two lateral movements: translation and alignment. To assess the performance of the cant positioning system, you need to check that the mechanical systems are capable of delivering both types of movement with sufficient accuracy. To do this, you must sample cant production, draw reference lines on cant faces, and saw them in order to measure positioning errors.

7.1.1 Sampling

A sample of 30 to 50 cants is adequate to verify cant positioning. The sample should consist of a variety of cants representing the mill's production with respect to thicknesses, widths, and lengths. Flat cant faces should be free of mechanical damage or excessive sawing variations. Avoid twisted cants; they typically result from inadequate restraint during the primary breakdown allowing the log to rotate. You also need to ensure that the two faces of the cants are perfectly parallel; if they are not, it will be difficult to properly feed the cants into the bull edger, and they will tend to shift to one side. Reasons for cant faces not being parallel include poorly tensioned saw blades, in the case of circular saws, and improperly aligned bottom and top guides in the case of bandsaws.

7.1.2 Equipment Required

- Chalk line,
- Marker pens or numbered plastic tags,
- Digital camera,
- Steel rule or digital calliper.

7.1.3 Cant Marking and Identification

Identify each cant with a unique number on one end section, either with a marker or with a plastic tag. Using the chalk line, draw a reference line along the top face of the cant as shown in Figure 8; this reference line should be parallel to the feeding orientation into the scanner, and you need to know the distance from the reference line to the stop lug (in a transverse system) or to the guide-bar (in a linear system). If the cants are scanned on a chain deck or a conveyor belt, the reference line should be aligned with the position of the “zero” saw (red arrow in Figure 8). Dotted lines correspond to the paths of the other saws in the bull edger.

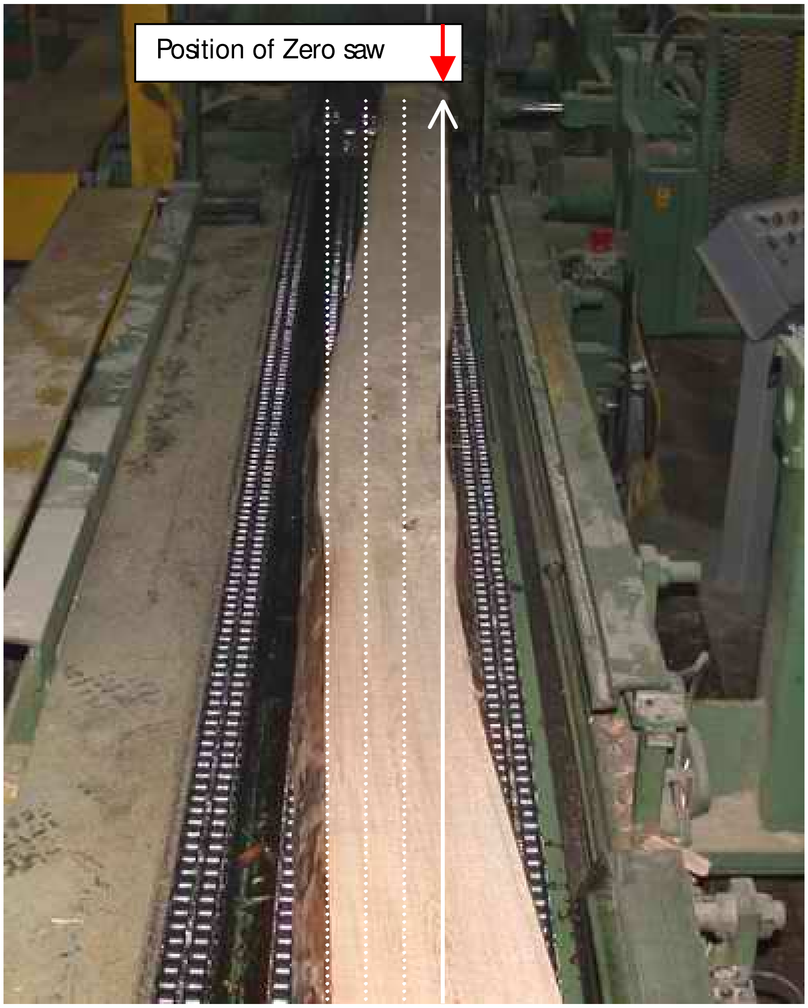


Figure 8. Cant being fed on a chain deck

7.1.4 Cant Breakdown

You need to saw the cants one at a time because all cuttings must be recovered at the outfeed. The concept of the evaluation is to monitor the reference line on one or more cuttings in order to measure any displacement (at the front end or the rear end) that may have been caused by the positioning deck. In addition, you need to capture this information from the optimizer's interface, where it is usually available.

7.1.5 Results Analysis

To quantify positioning errors, all you need to do is compare your own measurements to the values provided by the optimizer. By compiling deviations, you develop a statistical analysis of positioning errors (front and rear), as shown in Table 6. You can also develop a histogram of positioning errors (Figure 6) for easier visualization of such errors. Results based on our own sample yielded average front and rear positioning errors of 0.053 and 0.109 inch respectively.

Table 6. Descriptive statistics of cant positioning errors

Statistical indicators	Front offset	Rear offset
Average	0.109	0.053
Median	0.160	0.055
Standard deviation	0.132	0.186
Skewness coefficient	-0.618	-0.503
Range	0.432	0.624
Minimum	-0.141	-0.317
Maximum	0.291	0.307
Number of specimens	16	16

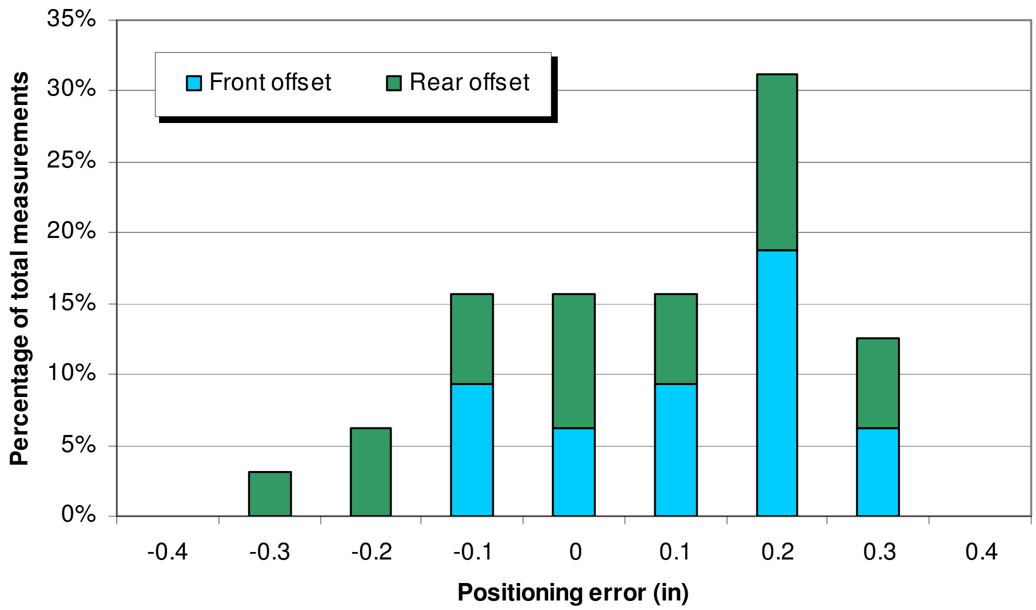


Figure 9. Histogram of cant positioning errors

8 Evaluation of Optimization Software

8.1 Optitek Simulations

To evaluate a commercial optimization software program, you need to use another optimization program. The method described in this section relies on the Optitek simulator, which can be used to replicate the operation of a commercial optimizer. This method involves relatively sophisticated simulation concepts, and it is intended for experienced Optitek users.

8.1.1 Optitek Log Format

To assess a manufacturer's optimization software, you have to have access to the measurement data provided by the relevant scanner. Most equipment manufacturers willingly release their data format. The information is usually provided in text files structured for easy conversion to a spreadsheet format such as Excel. In some instances, however, log files are not accessible, or they are structured in such a way that they cannot be adapted; when this happens, your only option is to ask the manufacturer to provide the required information, or to request that the scanner data be adapted to the Optitek format. Appendix I illustrate the various log file formats recognized by Optitek. Structures vary according to scanner type (*xy* or 3D).

Several manufacturers have already integrated the Optitek log format to their interfaces. With this option, users can save log profiles in the Optitek format and perform their own simulations.

8.1.2 Breakdown Optimization

Once you are capable of capturing the scanner's data and saving such data in a known format, your next step is to model the mill, which consists in parameterizing all optimized breakdown equipment elements with the Optitek simulator. At this stage, you need to decide on the desired optimization level to compare the commercial optimizer to the Optitek simulator. Simulation times rise rapidly as the optimization level increases; if the optimization level is unrealistically high, results may be unrealistic and simulations are likely to be extremely slow; on the other hand, low optimization levels may generate misleading results. An optimization level ensuring 99% value recovery is considered adequate to assess an optimizer. You may want to keep in mind that the simulation time is directly proportional to the number of computation runs (iterations) involved.

Optitek has been used to perform sawing simulations involving different numbers of log or cant positioning runs, and determine required optimization levels at the primary and secondary breakdown stages.

8.1.3 Primary Breakdown Optimization

Table 7 presents the results of a simulation for various primary breakdown optimization levels. Volume recovery and production value per cubic metre are shown in relation to the number of runs processed by the simulator to maximize unit value, hence financial returns. Optimization efficiency is determined by the ratio of the resulting value recovery to maximum value recovery.

Table 7. Primary breakdown simulation results in relation to optimization level

Number of computation runs	Volume recovery (bf/m³)	Value recovery ($/m³)	Optimization efficiency
1 (no optimization)	291.0	116.19	93 %
2	292.2	120.51	96 %
6	291.4	121.71	97 %
9	292.3	121.78	97 %
15	296.8	123.46	98 %
25	298.6	124.32	99 %
45	301.4	125.29	100 %
63	303.0	125.49	100 %

A graphic representation of these results (Figure 10) shows that value recovery tends to reach a plateau beyond 45 runs; at that point, optimization efficiency is 100%. What we are trying to determine is the number of runs that will give us an efficiency level of 99%. In the case of the primary breakdown operation, this efficiency level is reached with 25 computation runs, including rotation situations (5) and lateral translations (5).

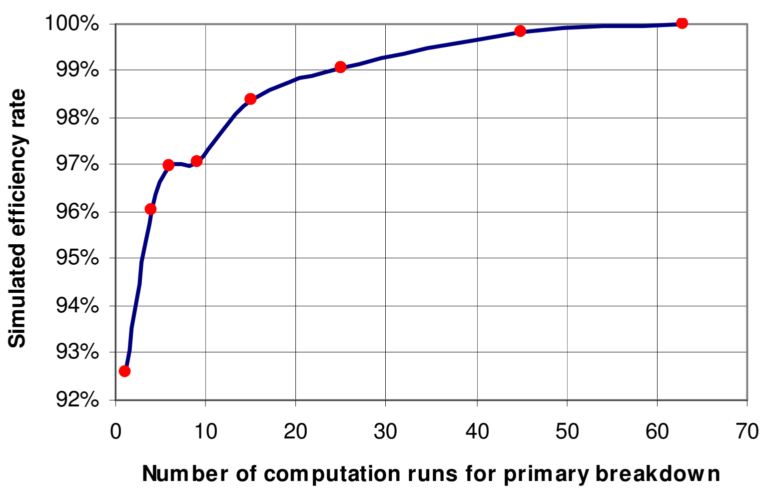


Figure 10. Impact of optimization level on primary breakdown

8.1.4 Secondary Breakdown Optimization

As with the primary breakdown, we have performed simulations to assess optimization efficiency in secondary breakdown operations. Table 8 displays the results of such simulations. In this case, the 99% optimization efficiency level is reached after about 15 computation runs combining cant lateral translation and alignment.

Table 8. Secondary breakdown simulation results in relation to optimization level

Number of computation runs	Volume recovery (bf/m³)	Value recovery ($/m³)	Optimization efficiency
1 (no optimization)	255.1	100.66	85 %
2	271.8	106.02	90 %
6	283.5	112.40	95 %
9	285.8	114.36	97 %
15	291.2	116.06	99 %
25	292.9	116.93	99 %
45	294.2	117.44	100 %
63	293.8	117.75	100 %

Figure 11 displays efficiency levels in relation to the number of computation runs. Here again, optimization efficiency tends to stabilize at 100% after some 45 runs. The overall shape of the curve is somewhat similar to that of the primary breakdown curve, with value recovery rising rapidly from 1 to 10 runs, and then stabilizing between 15 and 25 runs.

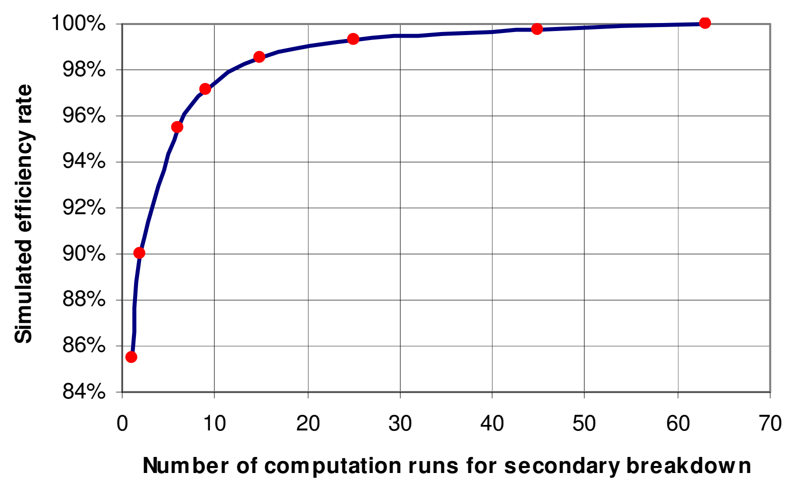


Figure 11. Impact of optimization level on secondary breakdown

8.1.5 Optimization Parameters

Tables 9 and 10 list primary and secondary breakdown optimization parameters that are frequently used to model sawmilling equipment with Optitek. Optimization of log breakdown is achieved through a series of computation runs designed to determine the log's best position in space by means of rotation and translation movements. The first step is to position the log with its sweep plane in a vertical position (horns down), and to centre it with respect to its sides; the various positioning scenarios are computed from that initial position. Rotations are restricted to a ±40° angle in 20° increments; as for translation, it is restricted to ± 0.4 inch in 0.2-inch increments. With twin bandsaws, kerf width usually varies in the 0.125-0.140-inch range, while, with twin circular saws, it is more likely to range between 0.140 and 0.160 inch.

Table 9. Optimization parameters – Primary breakdown

Initial positioning	Horns down, log centred in relation to its sides
Saw kerf	0.125 to 0.140 inch (bandsaw) 0.140 to 0.160 inch (circular saw)
Computed rotation positions	± 40° in 20° increments (5 positions tested)
Computed translation positions	± 0.4 inch in 0.2-inch increments (5 positions tested)
Total number of positions computed	5 rotations x 5 translations = 25 runs

To optimize the breakdown of a cant, several positions are similarly tested to identify the optimum sawing pattern. Initially, the scanned cant may be resting against the guide-bar, which makes it off-centred to the concave side of the curve. Other systems provide for cant scanning on a conveyor belt or a chain deck; in both these cases, the cant is initially centred. The optimizer then identifies the cant's optimum position by testing translation movements in 0.4-inch increments over a 1.6-inch range, as well as alignment displacements in the 0 ± 0.3° range. For every translation/alignment combination, the optimizer computes a curve-sawing path according to a second-degree polynomial equation if only one curve is allowed, or a third-degree polynomial equation if two different sawing curvatures are possible ("S" shape sawing). The polynomial makes it possible to simulate a perfectly curved cut while taking into consideration the minimum radius of curvature set by the user (typically between 1,500 and 4,000 inches). In the bull edger, the cant is processed by a series of circular saws with kerfs ranging from 0.120 to 0.140 inch. The system usually allows for one board to be resawn from one side of the cant (both sides in some cases). Only one piece can normally be edged on each side of the cant.

Table 10. Optimization parameters – Secondary breakdown

Initial positioning	Centred (if scanned on a conveyor belt or a chain deck) Offset to concave side (if scanned against a guide bar)
Curve sawing path	2nd degree polynomial (simple curve sawing) 3rd degree polynomial ("S" shape sawing)
Minimum radius of curvature	1,500 to 4,000 inches
Saw kerf	0.120 to 0.140 inch
Number of sawblades	As required
Target thicknesses	1.650 to 1.750 inches
Resawing and edging potential	One board off concave side or one board on each side – maximum 2 boards
Computed alignment positions	± 0.3° in 0.3° increments (3 positions tested)
Computed translation positions	± 0.8 inch in 0.4-inch increments (5 positions tested)
Total number of positions computed	3 alignments x 5 translations = 15 runs

This information will serve as guidelines to decide on an optimization level for the simulator. You always have the option of raising or lowering this level to accommodate specific needs, but we recommend that you proceed gradually and keep an eye on the results as you go.

8.2 Breakdown Efficiency

Breakdown efficiency is measured by the volume and value recovery achieved by the equipment as a percentage of the maximum levels computed by the optimizer. This efficiency rate provides a good indication of the ability of the positioning system to implement the solutions recommended by the optimizer. To maximize lumber volume and value recovery, you should also consider assessing the performance of your optimization software. Table 11 shows a typical calculation of efficiency levels based on a 30-odd log sample. In this particular example, the production line managed to recover 98.5 % of the lumber volume estimated by the commercial optimizer, the value recovery being 96.5% of the target set by the optimizer. In terms of value, the equipment was therefore running at 96.5% efficiency in relation to its own optimization system. A comparison involving the commercial optimizer and the Optitek simulator showed similar volume recovery levels, but value recovery was 1.9% higher with Optitek, which implies that the commercial optimizer was running at 98.1% efficiency for value recovery. Consequently, the actual optimization efficiency level of the system was 94.6% in relation to the maximum value calculated by Optitek.

Table 11. Typical calculation of efficiency factors for a commercial optimizer

Efficiency factor	Yield (bf/m³)	Lumber volume recovery (bf)		Lumber value recovery ($)	
Optitek simulator	287.8	802.17	-	368.10	-
Commercial optimizer	288.3	803.33	100.1 %	361.00	98.1 %
Test results	283.8	790.92	98.6 % (98.5 %)	348.22	94.6 % (96.5 %)

Note: The percentage in brackets refers to the commercial optimizer

8.3 Validation of Efficiency Results

At this stage, it is desirable to verify the validity of these results by means of linear regression analyses based on the results obtained from individual logs. By comparing results from the commercial optimizer, the Optitek simulator, and actual mill tests, you can develop a correlation based on lumber volume and value. The determination coefficient R^2 serves as an indicator of the system's efficiency. In fact, this coefficient indicates to what extent the points are grouped (or scattered) around the regression line. A determination coefficient R^2 equal to 1 would signal a perfect correlation between the two variables considered, while an R^2 of 0 would indicate the absence of any correlation. The closer the coefficient is to 1, the better the correlation. Figures 12 and 13 show the correlations obtained for volume and value recovery. With R^2 values higher than 0.95 (hence close to 1), efficiency results can be considered valid for all logs.

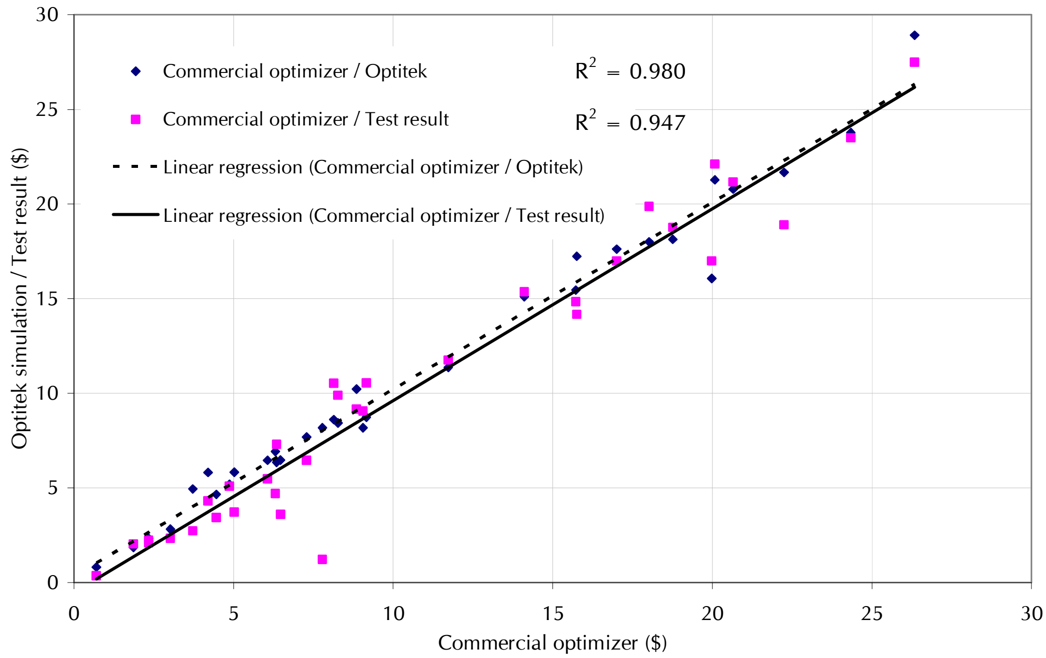


Figure 12. Regression analysis based on lumber volume recovery

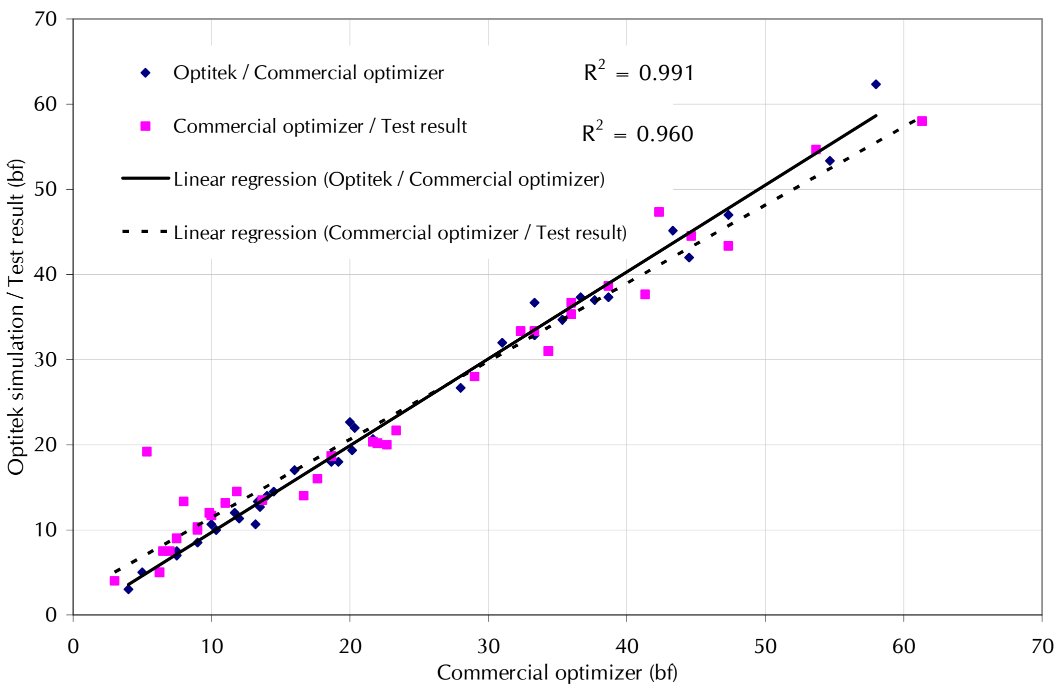


Figure 13. Regression analysis based on lumber value recovery

9 Process Control Method

The performance of log breakdown equipment cannot be evaluated without in-depth analyses of the various components involved, but signs can be observed indicating inefficient operation or major dysfunction of the optimization process. This section of the guide provides a checklist of simple verifications to help mill personnel with the development of their own process control program.

9.1 Periodic Scanner Calibration

Scanner calibration must be checked periodically, and recalibrations carried out as required. The frequency of such inspections should be based on experience, but, in our opinion, a weekly schedule would be reasonable. Optimization efficiency can be greatly affected by inaccurate readings; considering that sawmill operators rely on performance indicators based on volume recovery, they need accurate information from the scanners. The calibration method using PVC pipes is relatively simple and not overly time-consuming. A single person can usually perform this verification during break time or over the lunch period.

9.2 Verification of Optimization Parameters

The individual responsible for optimization should maintain a logbook of all parameters relating to all optimizers. Every time any parameters are modified, a paper copy of the new configuration should be printed with its date of application. If need be, you will be able to go back to the old configuration if anything happens after the parameters have been modified.

There should be some consistency between the parameters used in the various optimization systems. If, for example, you modify operating parameters in one machine, you need to make sure that this will not conflict with other aspects of the breakdown process.

In view of the degree of equipment accuracy typically found in sawmills, the adoption of clearly distinct product specifications is an advantage. A multiplicity of lumber grades tends to slow down the optimization process, in addition to making verifications more cumbersome. One or two grades per product are generally adequate for excellent optimization results.

9.3 Daily Verification of Optimizer Efficiency

For a daily check-up on your optimizer's efficiency, you only need to compare the solutions produced by the equipment to those recommended by the optimizer. A sample of 5 logs or cants selected daily off the production line provides sufficient monitoring of the breakdown process. Compile your results on an on-going basis in order to document the performance history of the equipment. Daily results can serve as a basis to develop process control charts that will help you detect situations when optimizer efficiency is out of control. Figure 14 displays a typical process control chart, where the average efficiency level has been set at 96% (green line) and the efficiency threshold (red line) at 90%.

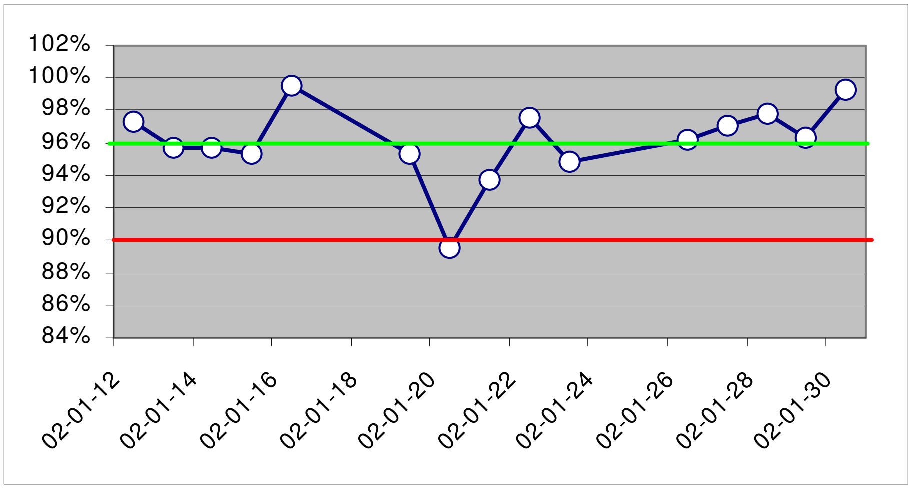


Figure 14. Typical optimizer efficiency control chart

If the equipment gets out of control, measures can be taken immediately (within a day) to identify what is causing the problem and correct it. Once corrections have been made, you need to conduct a new performance evaluation test to make sure that the process is safely back under control. The calculation methods used to determine control limits are essentially the same for all industrial processes.

The literature contains numerous documents or manuals dealing with the statistical control of industrial processes in general, and these can prove very useful to industry personnel wanting to develop process control charts. The following are examples of documents on this topic:

- BAILLARGEON. G. *Maîtrise statistique des procédés*. Les éditions SMG. 1992.
- KÉLADA. J. *Qualité: contrôle statistique et métrologie*. Éditions Quafec. 1990.
- PÉRIGORD. M. *Formation à la maîtrise statistique des procédés*. Les éditions d'organisation. 1990.

10 Conclusions

This guide is based on process evaluation techniques developed by Forintek's technical staff over the past decade in the course of a large number of mill assessments. We believe that this information will help production personnel improve sawmilling processes.

Analysis methods have been described in sufficient detail to allow for a comprehensive diagnostic of a mill's optimized breakdown equipment. This approach may appear time-consuming, but it provides a reliable appreciation of the optimized system's performance, in addition to identifying potential problems. The methods described are applicable to standard equipment commonly used for log and cant breakdown, but they can be adapted to specific equipment types or needs.

Analyses may be simplified, and sample sizes reduced to the point where evaluations can be integrated into a statistical process control program. Implementation of such a process control program requires a sound understanding of the optimized system's true capacity. And this requires a detailed analysis of the optimization system and all its components (i.e. scanner, optimization software, and positioning system).

11 References

Anon.. (2002*). L'INDEC 2001*. Quebec Lumber Manufacturers' Association. Sainte- Foy, QC. 37 p.

Anon. (2000). *Standard Grading Rules for Canadian Lumber*. National Lumber Grades Authority. New Westminster, B.C. 276 p.

BÉDARD, Pierre, et Jean MCDONALD (2001). *Optimized Trimming Efficiency*. Research Report. Forintek Canada Corp. Sainte-Foy, QC. 26 p.

LEWIS. D.W. (1985). *Yield losses from sawmill scanner error*. Forest Products Laboratory. Madison, WI. 12 p.

ORBAY, Laszlo. and Nicol DROUIN (1998). *Factor affecting the economic benefits of auto-rotation systems equipped with true shape scanner*. Research Report. Forintek Canada Corp. Sainte-Foy, QC. 38 p.

OVRUM. O. (2001). *Feeding accuracy into sawing machines*. Research Report. Norwegian Institute of Wood Technology. Oslo. 32 p.

Appendices

Appendix I Optitek Log File Format

Typical log file for a log measured with an xy scanner:

10 -------------------------------> unit of measurement
104 SansNom 1 5 -------------> description of log list
101 B#1 1 18 60 0 ------------> description of first log
16.1 16.7 17.7 14.61 0 -------> description of first section of first log
....
....
....
12 12.2 13 21.5 270.85 -------> description of last section of first log
101 B#2 1 20 60 0 ------------> description of second log
18 19.1 12.52 17.75 0 --------> description of first section of second log
....
....
.......etc.........

EXPLANATIONS:

unit of measurement:	10 = cm, 20 = in (variable)
description of log list:	104 = log list identifier (fixed) SansNom = log list name (fixed) 1 = log list number (fixed) 5 = number of logs in list (variable)
description of a log:	101 = actual log identifier (fixed) B#1 = name (variable) 1 = number of occurrences (variable) 18 = number of sections (variable) 60 = number of points per section (variable) 0 = polygonal model identifier (fixed)
description of a section:	16.1 = X diameter (variable) 16.7 = Y diameter (variable) 17.7 = X coordinate of centre (variable) 14.61 = Y coordinate of centre (variable) 0 = Z coordinate (variable)

Typical log file for a log measured with a 3D scanner:

10 -------------------------------> unit of measurement
104 SansNom 1 5 -------------> description of log list
105 c:\test\log1p.tsh 1 --------> description of first log
105 c:\test\log2p.tsh 1 --------> description of second log
....
....
.......etc.........

EXPLANATIONS:

unit of measurement: 10 = cm, 20 = in (variable)

description of log list: 104 = log list identifier (fixed)
SansNom = log list name (fixed)
1 = log list number (fixed)
5 = number of logs in list (variable)

description of a log: 105 = scanned log identifier (fixed)
c:\test\log1p.tsh = BINARY SCANNER DATA (variable)
1 = number of occurrences (variable)

with the following BINARY SCANNER DATA format:

Description	Size	Type
Number of sections	2 bytes	short integer
Z coordinate of first section	4 bytes	long integer
Number of points in first section	2 bytes	short integer
X coordinate of first point	2 bytes	short integer
Y coordinate of first point	2 bytes	short integer
....		
....		
....		
X coordinate of last point	2 bytes	short integer
Y coordinate of last point	2 bytes	short integer
Z coordinate of second section	4 bytes	long integer
Number of points in second section	2 bytes	short integer
X coordinate of first point	2 bytes	short integer
Y coordinate of first point	2 bytes	short integer
....		
....		
....		
X coordinate of last point	2 bytes	short integer
Y coordinate of last point	2 bytes	short integer
....		
....		
....		
Z coordinate of last section	4 bytes	long integer

Number of points in last section	2 bytes	short integer
X coordinate of first point	2 bytes	short integer
Y coordinate of first point	2 bytes	short integer
....		
....		
....		
X coordinate of last point	2 bytes	short integer
Y coordinate of last point	2 bytes	short integer

Notes:
1) X, Y and Z coordinates are multiplied by 1000. For example, 1234 = 1.234
2) Sections are in reverse order to the way they are fed into the machine (i.e. the fist section in this format is actually the last section scanned, and it should have the lowest Z coordinate.
3) Points in a section are listed clockwise as seen from the end whose section has the smallest Z coordinate. No point can be located anti-clockwise from a previous point.

Appendix II Evaluation Forms

This section contains illustrated forms that you can use to enter and process the information required for the assessment of log and cant breakdown equipment. These forms were developed from Excel spreadsheets, and they are available in electronic format on request

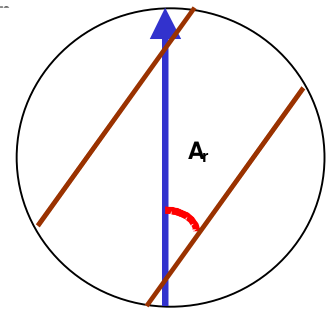
- Log Positioning Evaluation Form (without a digital camera)
- Log Positioning Evaluation Form (with a digital camera)
- Cant Positioning Evaluation Form

Log Positioning Evaluation Form

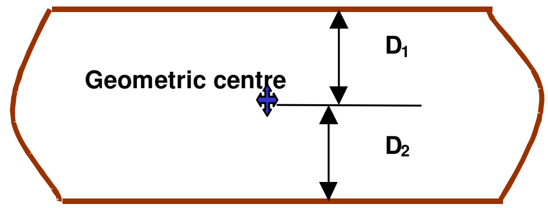
(Without a digital camera – errors measured directly off cants)

Rotation Test

Reference position horns down position



Centring Test



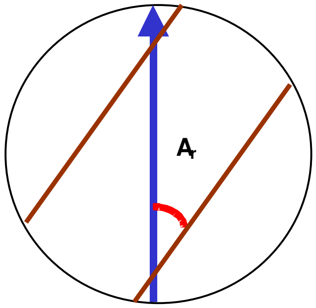
Log number	Rotation angle (A_r) (degrees)	Distance centre-to-top (D_1) (in)	Distance centre-to-bottom (D_2) ((in)	Offset (D_1- D_2)/2 ((in)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

Log Positioning Evaluation Form

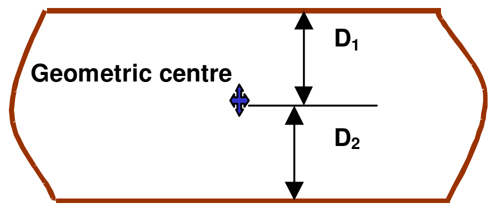
(With digital camera – errors measured off prints)

Rotation Test

Reference position horns down



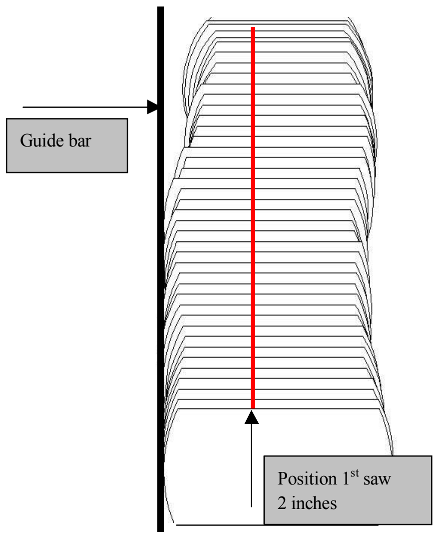
Centring Test



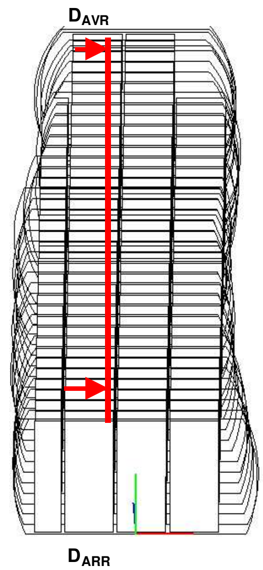
Log number	Rotation angle (A_r) (degrees)	Distance centre-to-top (D_1) (mm)	Distance centre-to-bottom (D_2) (mm)	Actual cant thickness (E) (in)	Offset $((D_1 - D_2)/2)*(E/(D_1+D_2))$ (in)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

Cant Positioning Evaluation Form

Before



After breakdown



Cant number	Front end optimizer (D_{AV}) (in)	Rear end optimizer (D_{AR}) (in)	Front end actual (D_{AVR}) (in)	Rear end actual (D_{ARR}) (in)	Front end D_{AV}-D_{AVR} (in)	Rear end D_{AR}-D_{ARR} (in)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						