Forintek Canada Corp.
Eastern Division
319, rue Franquet
Québec, QC G1P 4R4

General Revenue Project No. 4910

Final Report 2006-2007

# Comparison between Canter Infeeds
## – Primary Breakdown –

by

Pierre Bédard
and
Francis Fournier
Scientists
Lumber Manufacturing Technology Department

March 2007

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

Francis Fournier
Project Leader

Pierre Bédard
Reviewer

Yves Lévesque
Department Manager

# Notice

This report is an internal Forintek Canada Corp. (Forintek) document, for release only to Forintek members. This distribution does not constitute publication. The report is not to be copied for, or circulated to, persons or parties other than Forintek members, except with the prior permission of Forintek. Also, this report is not to be cited, in whole or in part, unless prior permission is secured from Forintek.

Neither Forintek, nor its members, nor any other persons acting on its behalf, make any warranty, express or implied, or assume any legal responsibility or liability for the completeness of any information, apparatus, product or process disclosed, or represent that the use of the disclosed information would not infringe upon privately owned rights. Any reference in this report to any specific commercial product, process or service by trade name, trademark, manufacturer or otherwise does not constitute or imply its endorsement by Forintek or any of its members.

# Summary


Chipper-canter infeed technology has changed greatly over recent years. The self-centering mechanical devices installed in the 1970-1990 period have been replaced with more sophisticated systems that also control log alignment and translation. These optimized systems allow for improved yield, but they are also more complex and require more attention and maintenance. The purpose of this study was to compare four different infeed systems illustrating infeed technology evolution over time, as applied to small logs, where optimization and positioning errors are more critical.

Theoretical simulations of the four infeed types studied showed that a system optimized for both alignment and translation can produce 9% greater revenue than self-centering straps, as compared with 8% for a translation-only optimized system, and 5% for self-centering rollers.

In mill tests, a system optimized for alignment and translation yielded 8% greater revenue than the basic self-centering straps, as compared to 6% for the translation-optimized system, and 5% for the self-centering roller device. Actual efficiency ranged from 91 to 93% independently of technology level, as it was determined by mechanical damage, sawing variation and rotation errors.

According to our evaluation of mechanical damage to lumber in the canters, losses averaged $11/Mbf, but the results varied significantly, ranging from $3 to $16/Mbf. Defects were mostly related to cutting parameters and knife maintenance, rather than the technology level of the equipment. Of the four types of equipment in the study, three would have benefited from a pre-cutting saw to minimize damage, as the loss of chips associated with sawkerfs amounted to $6/Mbf.

Rotation errors had less impact on optimized infeeds than on mechanical self-centering devices thanks to a second – post-rotation – optimization. Our simulations showed that rotation errors could reduce efficiency by 7% in the case of self-centering straps, 4% with self-centering rollers, but only 1% with optimized systems of both types.

# Acknowledgements

Forintek Canada Corp. wishes to thank the following individuals for their assistance with the performance of this study:

| | |
|---|---|
| Gabriel Côté | Abitibi Consolidated |
| Christian Dionne | Canfor (Daaquam Lumber) |
| Yvon Hubert | Comact Optimisation |
| Pierre Gariépy | Fontaine-Lumber |
| Sébastien Crête | Gérard Crête et Fils |
| François Bernard | Matériaux Blanchet |
| Sylvain Boulianne | Sawquip Internationnal |

# Table of Contents

# List of Tables



# List of Figures

# 1 Objectives

To compare the different chipper-canter infeed systems, and analyze their efficiency in order to improve overall mill performance.

# 2 Introduction

Most Canadian sawmills use chipper-canters for the primary breakdown operation. When applied to process logs of 16 cm and over in diameter, they are frequently combined with twin-blade saws that provide patterns including sideboards. They are also used at the secondary breakdown stage, where they reduce the need to sort slabs after the bull edger, and minimize the sawdust from two sawkerfs by replacing it with chips.

At both the primary and secondary breakdown levels, log positioning and infeed techniques used with canters have changed since the 1970s. Mechanical self-centering devices have been in common use to maintain and position the logs as they are fed into the canter. They used to be applied with both small- and large-diameter logs. A number of Eastern Canadian mills still use them. Optimized systems developed in the 90s allowed for improved canter infeed. Thanks to scanners and optimizers, it has become possible to position the logs in rotation, alignment and translation. The most recent systems can be equipped with continuous log positioning systems.

# 3 Background

From 5 $m^3$/Mbf in the 90s, the wood consumption factor is now down to 4 $m^3$/Mbf. To a large extent, equipment performance and technology have contributed to such improvement. The introduction of scanners to determine log and cant shapes as well as optimum positioning and cutting pattern has led to lower wood consumption and maximum product value. Simulations show that greater reliance on optimization yields enhanced mill performance. Optimized positioning produces recovery gains of more than 10% at the secondary breakdown stage as compared to a guide-bar, and by more than 5% over a self-centering device at the primary breakdown stage.

A number of studies have shown, however, that the anticipated solution frequently fails to be achieved because mechanical systems are insufficiently accurate to avoid positioning errors. For a given error level, the effect will be greater on smaller diameter logs. In view of the level of positioning errors due to mechanical equipment, it may be preferable to optimize the positioning of small logs or, more simply, to just try and centre them properly in the canter.

# 4 Technical Team

| | |
|---|---|
| Pierre Bédard | Scientist, Lumber Manufacturing Technology |
| Francis Fournier | Scientist, Lumber Manufacturing Technology |
| Luc Bédard | Technologist, Lumber Manufacturing Technology |
| Yves Giroux | Technologist, Lumber Manufacturing Technology |
| Ghislain Veilleux | Technologist, Lumber Manufacturing Technology |
| Jean McDonald | Scientist, Lumber Manufacturing Technology |

# 5 Materials and Methods

We compared canter infeed techniques through a combination of actual mill studies and simulations with the Optitek software. Figure 1 illustrates the methodology applied to the study, and the following sections describe the four infeed types under study as well as the steps involved.

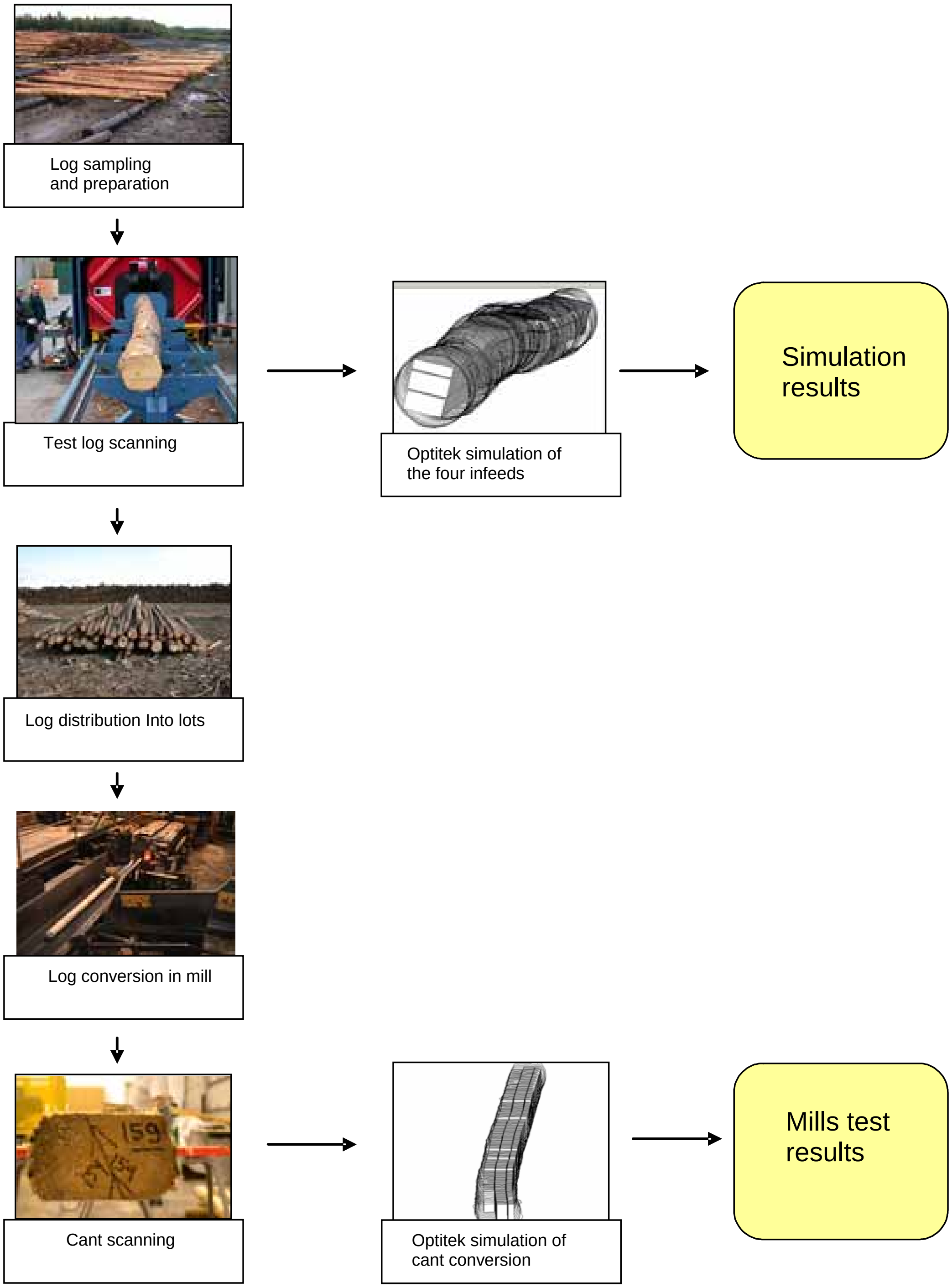



***Figure 1  Methodology applied to the study***

## 5.1 Canter Infeed Techniques under Study

The study covered four canter infeed techniques used for primary conversion:

- a self-centering strap device;
- a self-centering roller device;
- a translation-optimized system;
- a fully optimized system for translation and alignment.

### 5.1.1 Self-centering Strap Device

Devices of this type became popular in the 1970s. Being simple and easy to maintain, they are still used in a number of Eastern Canadian mills. The length of the self-centering straps varies with the lengths of logs to be processed and the desired length of the centering section. Chains may occasionally be used in lieu of straps, with no effect on centering results. Figure 1 illustrates the self-centering technique.

This device is typically combined with a manually operated log-turner. The operator feeds the logs horns down. Following rotation, the logs enter the self-centering strap section before being fed into the chipper-canter. Two rollers located between the straps and the canter maintain the logs and prevent further rotation during processing.

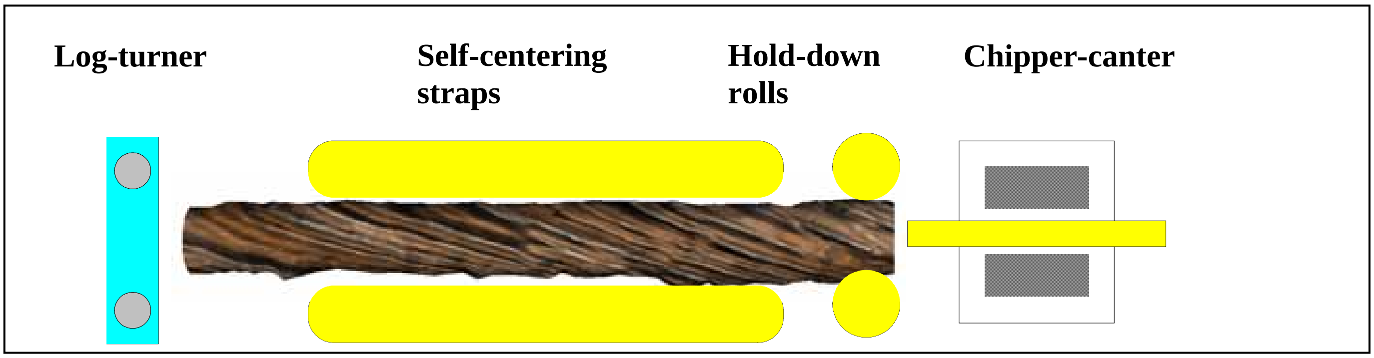



***Figure 2 Self-centering device***

### 5.1.2 Self-centering Roller Device

This is similar to self-centering straps. The self-centering roller device was developed in the 1980s, and installed until the end of the 1990s. Although it is more complex than the self-centering straps, ease of maintenance explains its continuing use in a number of sawmills. In this case, centering is obtained by means of rollers rather than straps. The distance between successive pairs of rollers determines the length of the log centering section. Figure 2 illustrates this device.

In the system under study, an automatic log-turner positioned the logs horn down. The infeed was equipped with three pairs of rollers, which limited the effect of knots and other shape defects on log centering. Hold-down rolls located just before the canter helped maintain the logs in position during processing.

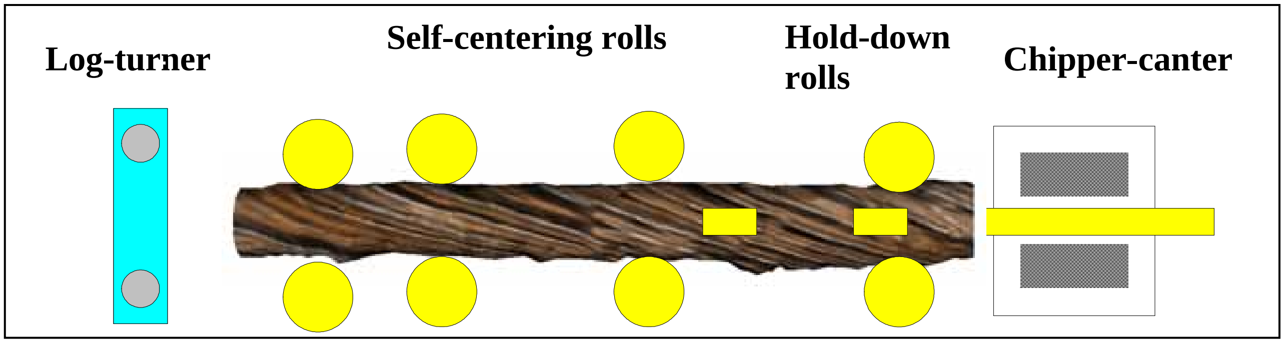



*Figure 3  Self-centering roller device*

### 5.1.3 Translation-optimized System

Translation-optimized systems appeared in the 1990s in line with the development of scanners and optimization systems. This system is far more complex than its predecessors. It relies on scanners, an optimizer and mechanical components to optimize and control log positioning in translation. It also requires much more attention and maintenance than the mechanical centering devices.

Figure 4 illustrates this technique. The system used in our study obviously used an automatic log-turner. In addition to optimizing log position (horns down), the scanner optimized the log's position in translation. The log was then turned and shifted over a scale chain within the infeed section. More scanners located inside the infeed supported a second translation optimization based on actual log rotation and centering. Several mechanical components shifted the log in translation before it entered the canter. Hold-down pads were used to maintain the log's position during processing.

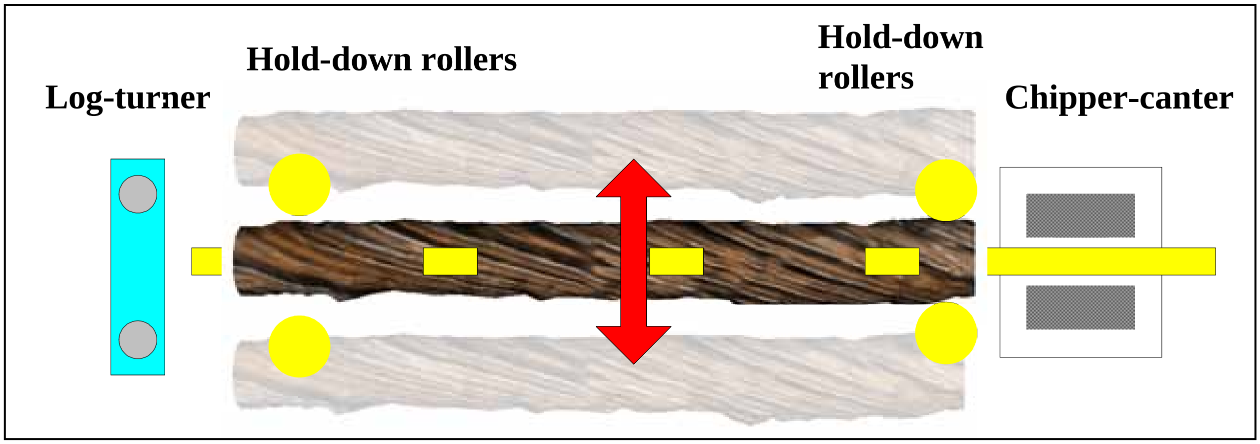



*Figure 4  Translation-optimized system*

### 5.1.4 Translation and Alignment Optimization System

Systems of this type, which were developed in the early 2000s, allow for total log positioning control in terms of rotation, translation and alignment. They make use of scanners, optimizers and mechanical components. Figure 4 illustrates the system used in our study.

A first scanner located before the log turner served to optimize log positioning in terms of rotation, translation and alignment. The log was rotated and fed into the infeed section. Inside the infeed, more scanners measured the log's position in space in real time, and determined adjustments required to bring the log back into its optimum position with the assistance of positioning rollers that also served to hold the log as it shifted horizontally.

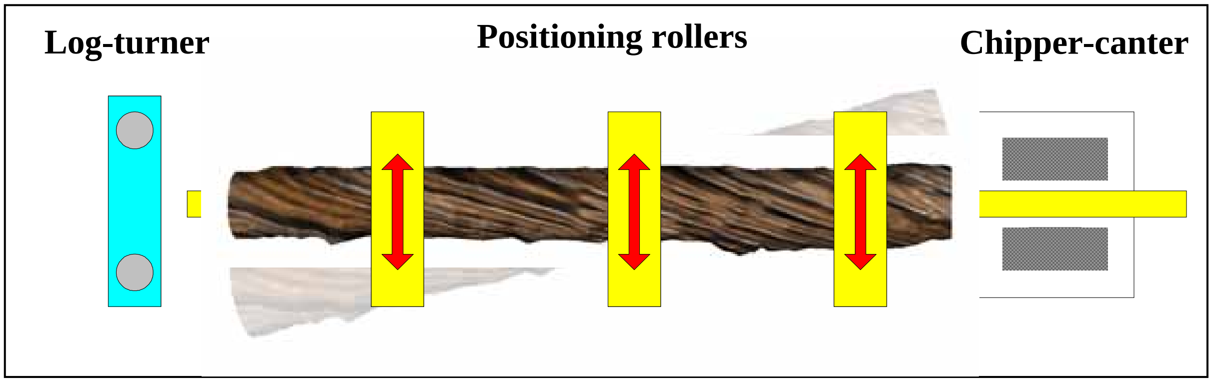



***Figure 5 Translation-alignment optimization system***

## 5.2 Log Sampling and Lot Development

To study the four canter infeed techniques, we applied a combination of Optitek simulations and mill tests requiring four lots of comparable log specimens.

### 5.2.1 Measurement of Log Specimens

We selected more than 330 logs in a sawmill yard (see Figure 5) on the basis of the following criteria:

- suitability for a 0-4-0 breakdown pattern;
- 16 feet in length;
- no major defects (e.g., rot, crook, fork, debarker damage);
- small-end diameter between 10 and 14 cm.

The log specimens were shipped to the Forintek laboratory for measurement with a portable scanner, and identification with a reference number and arrow at both ends.

***Figure 6  Log sampling***

### 5.2.2 Development of Four Similar Log Lots

All log measurements were converted into Optitek format. We then used dimensional characteristics (i.e., length, small- and large-end diameters, volume, curvature and taper) to create four lots of comparable logs. Table 1 shows average characteristics for the four test lots.

***Table 1  Characteristics of log specimen lots***

| Lot | Number of logs | Average length (m) | Average volume ($dm^3$) | Average taper (cm/m) | Average curvature (cm/m) |
|---|---|---|---|---|---|
| A | 83 | 4.97 | 87.36 | 1.01 | 0.68 |
| B | 83 | 4.97 | 87.84 | 1.00 | 0.64 |
| C | 83 | 4.96 | 88.11 | 1.01 | 0.67 |
| D | 83 | 4.96 | 88.11 | 1.00 | 0.63 |

## 5.3 Log Breakdown

Each of the four lots was randomly assigned to one of the four infeed systems under study:

Lot A: Self-centering straps;
Lot B: Self-centering rollers;
Lot C: Optimized translation;
Lot D: Optimized translation and alignment.

The logs were processed in a mill according to the selected technique. We recovered the cants produced by the canters and shipped them to Forintek for further study. As each log was being processed in the mill, one face of the cant was identified (left or right) for measurement of the rotation angle at breakdown time.

## 5.4 Cant Analysis

For each cant, we measured the cutting angle by comparison with the reference arrow to measure errors in rotation angle. We measured the cants for thickness to determine thickness average as well as thickness variation in relation to the four infeed techniques (see Figure 6). We also developed a qualitative assessment of fibre tear-out due to canter processing.


***Figure 7 Laboratory analysis of test cants***

## 5.5 Infeed Technique Simulations

Using Forintek's portable scanner, we measured the cants to quantify their true shapes for simulation with Optitek. We then modelled secondary breakdown, edging and trimming operations with Optitek. **As modelling allowed us perfect control over post-primary operations, we were able to isolate the effects of the different infeed techniques.** Figure 7 shows a cant measured with the portable scanner and simulated with Optitek. The secondary breakdown simulations assumed natural curve sawing to a radius of 500 inches and centered positioning. The kerf applicable to the bull edger blades was set to 0.125 inch, with a target thickness of 1.688 inches for dimension lumber, and 0.938 inch for boards. A maximum of three pieces could be recovered from each cant, and only one board was allowed.

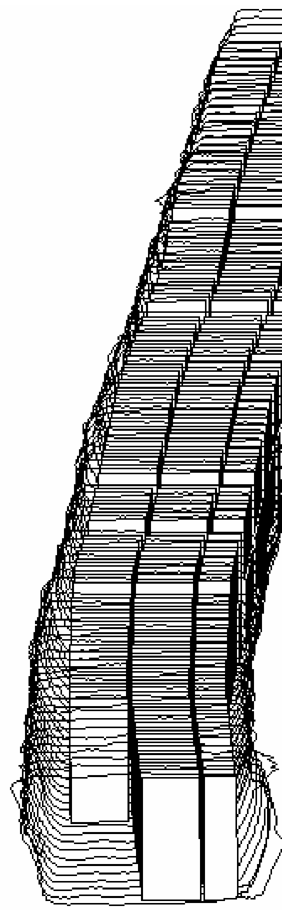


***Figure 8  Scanned cant simulated with Optitek***

The products derived from the simulation are commonly manufactured in a majority of mills, e.g., 2x4 and 2x3 dimension lumber in lengths of 5’ to 16’, and 1x3 and 1x4 boards from 5’ to 16’. Table 2 describes these products. Wane rules were as per NLGA for common lumber grades.

***Table 2  Description of simulated production***

| Products | Lengths (ft) | NLGA grades | Base wane (%) | Equivalent wane (%) |
|---|---|---|---|---|
| 1x3 | 6 – 16 | Utility & Better | 65 x 65 x 100 | 86 x 75 x 25 |
| 1x4 | 6 – 16 | Utility & Better | 65 x 65 x 100 | 86 x 75 x 25 |
| 2x3 | 5 – 8 | Stud | 35 x 55 x 100 | 55 x 80 x 25 |
| 2x3 | 10 – 16 | No. 2 & Better | 35 x 35 x 100 | 70 x 55 x 25 |
| 2x4 | 5 – 8 | Stud | 35 x 55 x 100 | 50 x 40 x 25 |
| 2x4 | 10 – 16 | No. 2 & Better | 35 x 35 x 100 | 70 x 55 x 25 |
| 2x4 | 5 – 16 | No. 3 and 4 | 75 x 75 x 100 | 95 x 95 x 25 |

*Note: Wane tolerances are shown as percentages of thickness x width x length.*

Table 3 provides a price list, in \$/Mbf, representing average prices over a one year period. We used these prices to measure financial results, in \$/m³, as they represent the best indicator of mill performance.

***Table 3 Lumber selling prices (\$/Mbf)***

| | Lengths | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Products | 5' | 6' | 7' | 8' | 9' | 10' | 12' | 14' | 16' |
| 1x3 Utility & Btr. | - | 280 | 280 | 280 | - | 350 | 350 | 350 | 350 |
| 1x4 Utility & Btr. | - | 275 | 275 | 275 | - | 320 | 320 | 320 | 320 |
| 2x3 Stud | 208 | 260 | 326 | 353 | 353 | - | - | - | - |
| 2x3 No.1 & 2 | - | - | - | - | - | 358 | 358 | 439 | 454 |
| 2x3 No.3 | 208 | 260 | 260 | 260 | 260 | 260 | 260 | 325 | 235 |
| 2x4 Stud | 282 | 353 | 351 | 459 | 473 | - | - | - | - |
| 2x4 No.1 & 2 | - | - | - | - | - | 444 | 481 | 480 | 480 |
| 2x4 No.3 | 225 | 280 | 280 | 390 | 390 | 390 | 390 | 390 | 390 |
| 2x4 No.4 | 225 | 280 | 280 | 266 | 280 | 280 | 280 | 280 | 280 |

# 6 Results

## 6.1 Simulated Results for the Four Canter Infeed Techniques

We determined the theoretical performance of the four infeed techniques with Optitek. When modelling the four techniques, we made sure that the parameters were identical to those used in industry. We therefore reflected the optimization potential achievable with each technique. Table 4 summarizes the resulting volume and value recoveries. As expected, full optimization (translation and alignment) yielded the best results, while the self-centering strap device offered the lowest performance. Volume recovery was maximum at 276.7 bf/m³ with translation-alignment optimization, compared with 257.5 bf/m³ with self-centering straps, the corresponding value recoveries being \$123.07/m³ with full optimization, and \$112.47/m³ with the straps.

With the self-centering roller device, volume recovery was 4.5% higher than with the straps, while value recovery was 5.3% higher. Although log centering is obtained mechanically with both devices, the roller system better followed exterior log profiles and proved less sensitive to log deformities than the straps. The translation-optimized infeed yielded 6.4% more lumber than the straps, for an 8.3% increase in value. With the addition of alignment optimization, the potential increase reached 7.4% for volume recovery and 9.4% for value recovery.

***Table 4 Simulated results from test logs in relation to infeed type***

| Infeed types | Volume recovery (bf/m³) | Cumulative differential | Value recovery (\$/m³) | Cumulative differential |
|---|---|---|---|---|
| Self-centering straps | 257.5 | - | 112.47 | - |
| Self-centering rollers | 269.0 | 4.5% | 118.44 | 5.3% |
| Translation optimization | 274.1 | 6.4% | 121.83 | 8.3% |
| Translation-alignment optimization | 276.7 | 7.4% | 123.07 | 9.4% |

## 6.2 Cant Simulation

This section discusses the results corresponding to the four infeed techniques in mill tests. Table 5 provides the simulated results obtained from mill-generated cants. The differentials on value recovery were similar to those obtained in the simulations, but we observed a different situation with volume recovery. Optimized infeed techniques did not yield superior volume recovery, and there were only small differences between the different techniques in the 257 to 259 bf/m³ range. Volume recovery differentials remained under 1%. It would therefore appear that optimized infeeds can produce higher quality lumber and generate greater value without increasing volume. The mechanical centering devices consequently led to a larger percentage of No. 3 and 4 grade pieces than the optimized infeed systems.

The value recovery differentials observed in the mill tests were comparable to those shown in Table 4 for simulations. The differential between self-centering rollers and self-centering straps remained in the order of 5%. The differential between the translation-optimized infeed and the straps was 6.2%, i.e. slightly smaller than in the simulation (8.3%), and the gain obtained with optimization for both translation and alignment stood at 8.0%, as compared to 9.4% in the simulation.

***Table 5 Simulated results according to infeed type for mill-produced cants***

| Infeed types | Volume recovery (bf/m³) | Cumulative differential | Value recovery ($/m³) | Cumulative differential |
|---|---|---|---|---|
| Self-centering straps | 257.0 | - | 104.30 | - |
| Self-centering rollers | 259.0 | 0.8% | 109.67 | 5.2% |
| Translation optimization | 257.3 | 0.1% | 110.72 | 6.2% |
| Translation-alignment optimization | 257.1 | 0.0% | 112.66 | 8.0% |

Table 6 and Figure 8 compare the value recovery results obtained from cant simulations based on simulated log breakdown and actual mill breakdown. The differential between the two value curves ranges from $8 to $11/m³. Calculated efficiency ratings reflect revenues obtained from in-mill evaluations (cant simulations) compared to theoretical revenues (log simulations). The efficiency of the translation optimized infeed turned out to be 91% as compared to 92% for the translation-alignment optimized system, and 93% for the mechanical self-centering devices. These efficiency ratings may sound low, but there are a number of possible reasons for this situation:

- Firstly, the theoretical levels simulated for the different infeed types are not currently achievable. Our simulations did not allow for errors in measurement (scanners), optimization (no limitation to the number of trials) and manufacturing (perfect log rotation and centering).

- Secondly, mechanical damage by chipper knives affected efficiency with all infeed types. Fibre tear-out resulted in lower lumber quality, excessive trimming and, occasionally, edging.

- Thirdly, positioning errors reduced infeed efficiency. Incorrect rotation resulted in improper log centering.

- Fourthly, target sizes and sawing variations affect trimming, edging and grade recovery. Cants that are too thin or contain excessive variation cannot yield high-grade, full-length lumber. Thickness variations may have been due to inadequate canter adjustment, poor knife installation, knife wear or excessive fibre tear-out.

***Table 6 Compared yields based on simulations from logs and cants***

| Infeed types | Yields calculated from logs ($/m³) | Yields calculated from cants ($/m³) | Differential |
|---|---|---|---|
| Self-centering straps | 112.47 | 104.30 | 93% |
| Self-centering rollers | 118.44 | 109.67 | 93% |
| Translation optimization | 121.83 | 110.72 | 91% |
| Translation-alignment optimization | 123.07 | 112.66 | 92% |

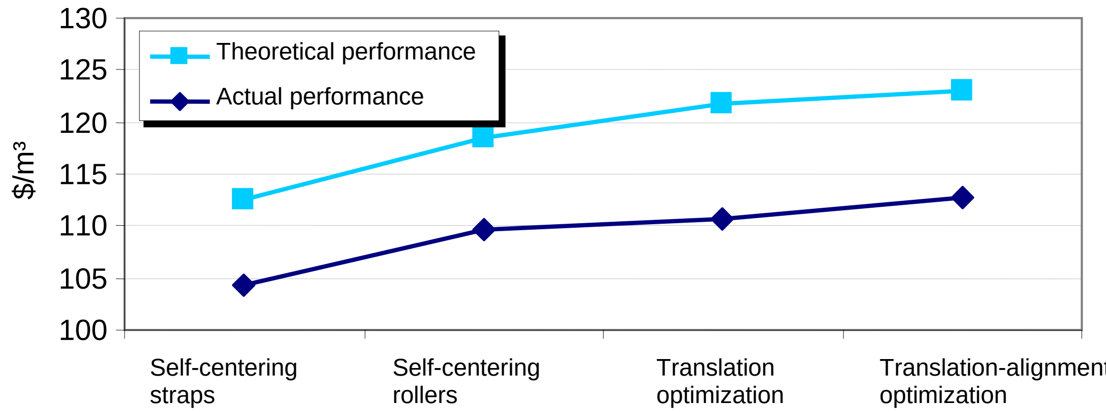



***Figure 9 Value recovery from simulations based on logs and cants***

## 6.3 Impact of Mechanical Damage due to Chipper

### 6.3.1 Occurrence of Mechanical Damage

For a qualitative evaluation of the occurrence and significance of mechanical damage on all test cants, we determined three levels of damage:

- Slight damage: tear-out with no effect on final grading, as the damage will be removed by planing.
- Moderate damage: fibre tear-out with potential effect on final grade and trimming. In most cases, volume recovery will not be affected.
- Severe damage: major fibre tear-out requiring edging and/or trimming. In all cases, volume recovery will be affected due to a significant loss of fibre from the cant.

Figure 9 shows percentages of cants with mechanical damage (three levels) in relation to infeed types. With the strap device, the roller device and the translation optimization system, we observed that more than 80% of the cants showed mechanical damage, as opposed to 60% for the translation-alignment optimization system. In addition, moderate and severe damage was more common with the self-centering roller infeed and the translation optimized infeed. However, previous Forintek research (Laganière, 2006) indicates that the infeed system is not necessarily responsible for mechanical damage at the canter. Other factors more likely to be involved include:

- cutting parameters (rotation speed, feed speed, cutting depth);
- knife types (disposable or not) and number of knives per head;
- knife adjustment.

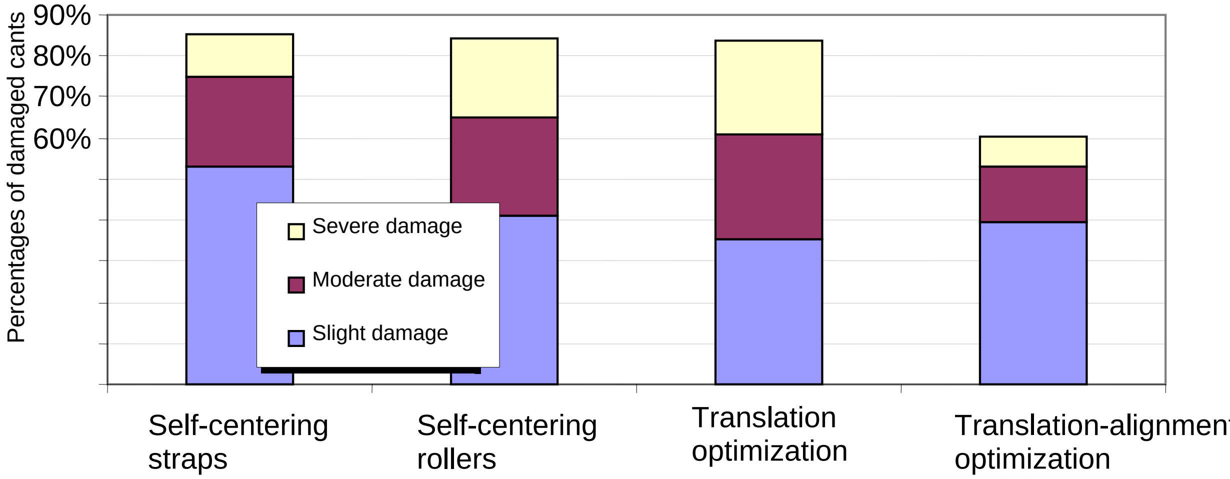



***Figure 10 Percentages of cants showing mechanical damage***

### 6.3.2 Simulation of Mechanical Damage Impact

We used simulations to assess the effect of mechanical damage on the performance of the different canter infeed types. Figure 10 illustrates how we filtered mechanical damage on a given test cant. The left-hand pictures show the cant as measured by the scanner and simulated with Optitek, while the right-hand pictures represent the same cant after filtering to produce straight lines. In this particular example, the unfiltered cant yielded two 2x4s and one 2x3. By simulating the filtered cant, we were able to produce three 2x4s, thus generating significant volume and value gains. We applied the same type of filter to all cants in our simulations to assess losses due to mechanical damage.

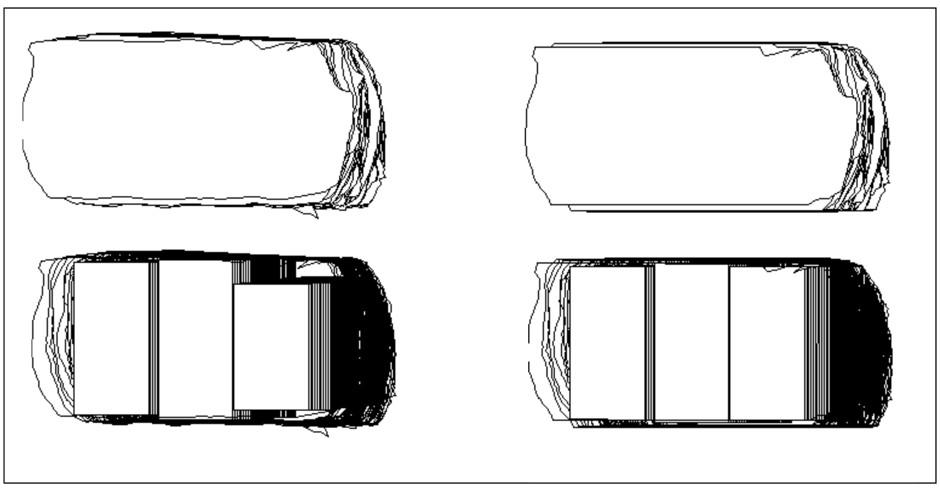


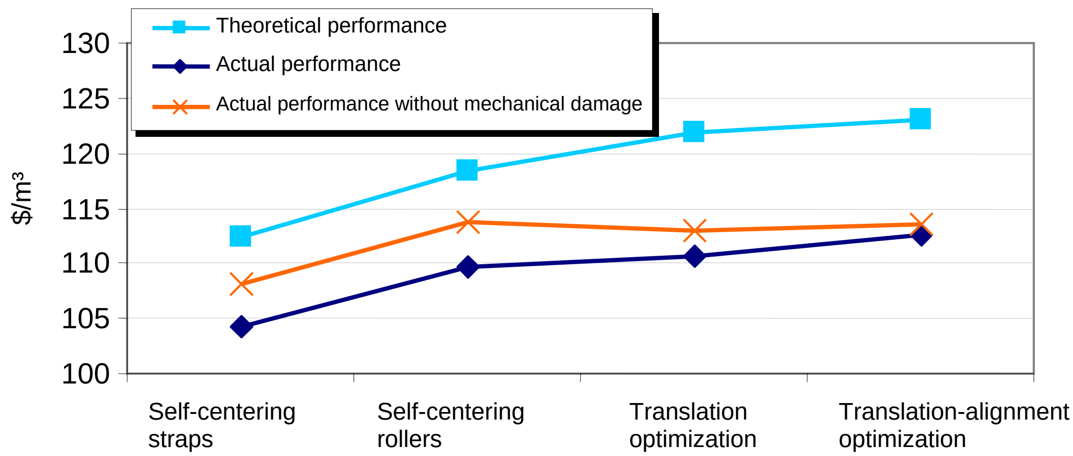
***Figure 11 Filtering of mechanical cant damage***

Table 7 shows the simulation results obtained from filtered cants. It is worth noting that this method can be used to determine the impact of mechanical damage. A different filtering algorithm could have produced different results, as other defects may be filtered together with mechanical damage.

### *Table 7 Simulation of mechanical damage impact for filtered cants*

| Infeed types | Volume recovery (bf/m³) | Cumulative differential | Value recovery ($/m³) | Cumulative differential |
|---|---|---|---|---|
| Self-centering straps | 252.9 | - | 108.10 | - |
| Self-centering rollers | 258.9 | 2.4% | 113.76 | 5.2% |
| Translation optimization | 256.7 | 1.5% | 112.97 | 4.5% |
| Translation-alignment optimization | 256.4 | 1.4% | 113.52 | 5.0% |

Figure 11 shows that, when mechanical damage was ignored, the value recovery differential between the self-centering straps and the fully optimized infeed (translation and alignment) tended to decrease. From 9.4% with the theoretical simulation on logs (Table 4) and 8.0% with the simulation based on mill-generated cants (Table 5), it decreased to 5% when mechanical damage was considered. As a result, the self-centering rollers achieved the same performance level as the optimized systems.




### *Figure 12 Value recovery from simulations based on logs, cants and filtered cants*

To calculate financial losses due to mechanical damage, we compared the results obtained from filtered cants (i.e. without mechanical damage) to those from unfiltered cants (i.e. with mechanical damage). Table 8 shows the corresponding losses in $/m³ and $/Mbf. Losses ranged from $0.86/m³ ($3.35/Mbf) to $4.08/m³ ($15.78/Mbf). The fully optimized infeed yielded the lowest damage-related loss, while it was highest with the self-centering roller infeed. On average, the loss due to mechanical damage stood at $2.75/m³, i.e. $10.73/Mbf. Given that damage-related losses are more closely associated to chipping parameters than to the type of canter infeed, any gains accruing from the use of optimized systems can be significantly reduced. It is therefore critical to optimize chipping parameters whatever the infeed type.

### *Table 8 Value loss due to mechanical damage*

| Infeed types | Volume loss | Value loss ($/m³) | Value loss ($/Mbf) |
|---|---|---|---|
| Self-centering straps | 1.6% | 3.80 | 15.04 |
| Self-centering rollers | 0.1% | 4.08 | 15.78 |
| Translation optimization | 0.2% | 2.25 | 8.75 |
| Translation-alignment optimization | 0.3% | 0.86 | 3.35 |
| Average | 0.5% | 2.75 | 10.73 |

### 6.3.3 Simulation of Saw Utilization

Chipping parameter optimization to minimize mechanical damage often leads to lower chip quality for the pulp & paper industry, and it is a commonly-held belief that mechanical damage by chipper-canters can never be totally eliminated. Forintek research in this area has been attempting to identify critical parameters in order to achieve an acceptable balance between fibre tear-out and chip quality.

Some manufacturers equip canter heads with post-cutting saws to improve surface finish quality, or with pre-cutting saws to minimize tear-out and achieve the same finish quality as with a saw. Unfortunately, the use of saws reduces chip production and generates more sawdust. To quantify the revenue loss corresponding to the lower chip volume, we simulated the following scenarios:

- Use of a post-cutting saw cutting no more than 0.030” deeper than the knives; and
- Use of a pre-cutting saw with a 0.140” kerf.

Since the issue hinges on by-products, we considered them in the calculations. Selling prices for chips and sawdust were assumed to be $125 and $25/bdmt respectively. The effect of the sawkerf on recovery and mill revenue is shown in Table 9. As can be observed, the use of post-cutting saws reduced value recovery by 0.4%, i.e. $1.76/Mbf. As for pre-cutting saws, they led to a value recovery loss of 1.2%, i.e. $6.32/Mbf. In practice, however, pre-cutting saws significantly reduce or even eliminate losses resulting from mechanical damage, while post-cutting saws only remove shallow tear-out defects. Consequently, whenever value losses due to mechanical damage exceed chip value losses associated with the use of saws, pre-cutting saws are a better option.

### *Table 9 Impact of sawkerf on mill revenue*

| Cutting tool types | Value recovery[1] ($/m³) | Cumulative differential | Revenue[1] ($/Mbf) | Loss ($/Mbf) |
|---|---|---|---|---|
| Chipping heads-No saws | 144.32 | | 529.68 | - |
| Chipping heads with 0.030” post-cutting saws | 143.69 | 0.4% | 527.92 | 1.76 |
| 0.140” kerf pre-cutting saws | 142.57 | 1.2% | 523.36 | 6.32 |

*1. Includes by-product revenue*

## 6.4 Impact of Rotation Errors

### 6.4.1 Rotation Errors in Mill Tests

Rotation errors represent a significant portion of positioning errors at the primary breakdown. Improper rotations lead to volume and value losses in addition to off-centering the log as it is processed. A variety of Forintek studies indicate that rotation errors average 0 degree (meaning that errors are similar on either side of the optimum position), with a standard deviation (S.D.) in the order of 25 degrees (all errors fall between -50 and +50 degrees). With the best log-turners evaluated, the standard deviation is about 15 degrees; lower deviation is also associated with high average log volumes and low feed speeds.

Using Optitek, we evaluated rotation errors with the different infeed types in relation to the horns-down position, which allowed us to assess the accuracy of the different systems on the same basis. Table 10 displays the rotation errors observed with each infeed type, while Figure 12 indicates what impact these errors had on the theoretical performance of the different systems.

Rotation error averages ranged from -8 degrees to +11 degrees. The smallest standard deviation was 29 degrees, observed with the fully optimized infeed system (translation and alignment), while the largest standard deviation was 42 degrees, with the self-centering strap infeed. In the latter case, an operator manually controlled log rotation.

***Table 10 Observed rotation errors***

| Infeed types | Averages (°) | Standard deviations (°) |
|---|---|---|
| Self-centering straps | 11 | 42 |
| Self-centering rollers | -3 | 38 |
| Translation optimization | 3 | 30 |
| Translation-alignment optimization | -8 | 29 |
| Average | 1 | 36 |

With each infeed type, we repeated the theoretical simulations using rotation errors such as measured off the logs in order to determine the best theoretical performance in view of the error rotations specifically observed in each case. As shown in Figure 12, rotation errors significantly reduced potential value recovery with the self-centering strap device. The theoretical maximum achievable when rotation errors were considered was only slightly better than the actual performance recorded in mill tests, which explained the differential between theoretical and actual performance. With the self-centering roller infeed, the theoretical performance when rotation errors were considered stood halfway between the theoretical performance and that observed in mill tests. With the optimized infeeds, consideration of rotation errors had relatively little impact on the theoretically achievable performance. As these systems provide for a second positioning opportunity (translation and alignment) after rotation, rotation errors have far less impact than they do with the mechanical centering devices.

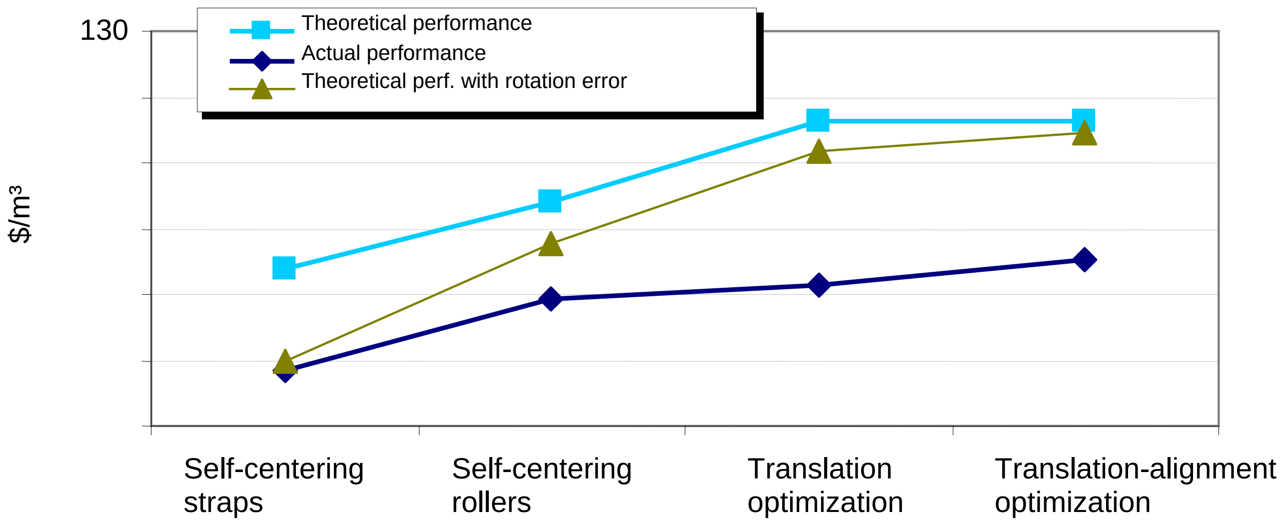



***Figure 13 Impact of rotation errors with the different infeed types***

### 6.4.2 Impact of Rotation Errors with the Different Infeed Systems

Optitek simulations conducted on four rotation error levels with the different infeed techniques provided a measure of the effect of error level on performance for each infeed type. Table 11 and Figure 13 display the results of these simulations.

With the mechanical centering devices, a higher level of rotation errors led to greater impact on volume and value recovery. With a strap device, for example, we obtained a 7% volume recovery differential between perfect rotation and a 35-degree standard deviation rotation error. In terms of value recovery, the differential was 9%. With a self-centering roller infeed under the same conditions, we found differentials of 5% and 6% respectively on volume recovery and value recovery. With the optimized infeed systems, however, rotation errors had less effect on recovery, as the logs can be repositioned in translation and alignment after the rotation process. With these optimized systems, the volume and value recovery differentials were no more than 3% between a perfect-rotation situation and one with 35-degree standard deviation rotation error. Up to 25 degrees in standard deviation error, losses due to rotation errors amounted to only 1%.

***Table 11 Simulation of rotation errors***

| Infeed types | Rotation error (S.D.) | Volume recovery (bf/m³) | Volume efficiency | Value recovery ($/m³) | Value efficiency |
|---|---|---|---|---|---|
| Self-centering straps | 0° | 257.5 | 100% | 112.47 | 100% |
| | 15° | 250.4 | 97% | 108.23 | 96% |
| | 25° | 245.4 | 95% | 105.98 | 94% |
| | 35° | 238.4 | 93% | 102.52 | 91% |
| Self-centering rollers | 0° | 269.0 | 100% | 118.44 | 100% |
| | 15° | 266.6 | 99% | 116.45 | 98% |
| | 25° | 261.9 | 97% | 114.02 | 96% |
| | 35° | 256.5 | 95% | 111.77 | 94% |
| Translation optimization | 0° | 274.1 | 100% | 121.83 | 100% |
| | 15° | 272.0 | 99% | 120.90 | 99% |
| | 25° | 271.7 | 99% | 120.05 | 99% |
| | 35° | 267.0 | 97% | 118.31 | 97% |
| Translation-alignment optimization | 0° | 276.7 | 100% | 123.07 | 100% |
| | 15° | 274.3 | 99% | 121.88 | 99% |
| | 25° | 273.8 | 99% | 121.38 | 99% |
| | 35° | 269.2 | 97% | 119.86 | 97% |

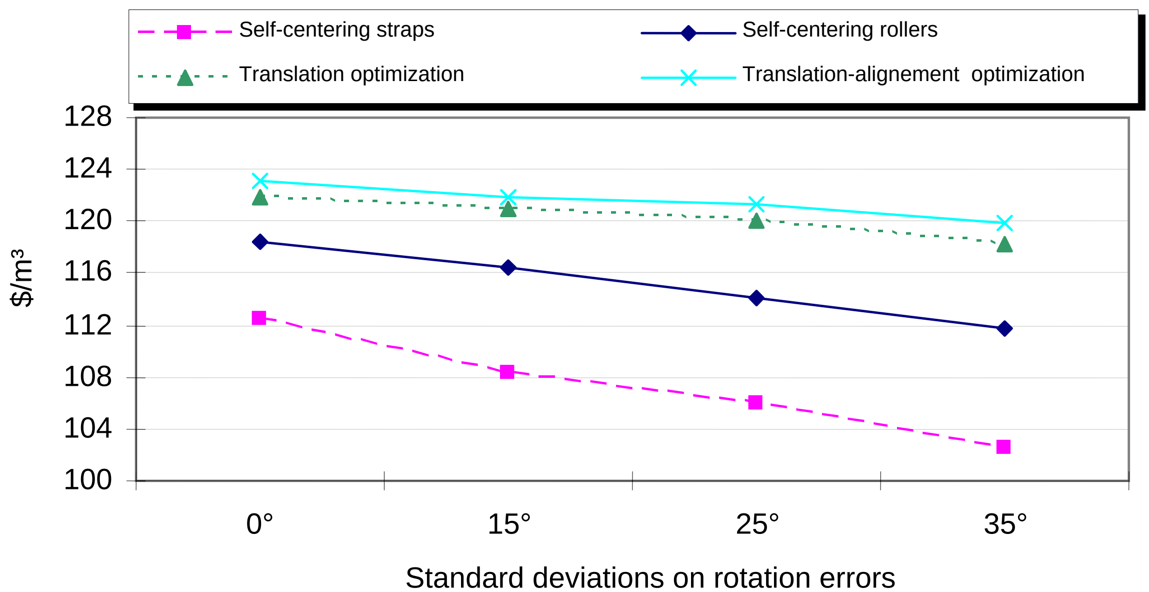



***Figure 14 Impact of rotation errors on value recovery***

## 6.5 Cant Thickness Variation

As thickness variations may affect trimming, edging and grading, they affect recovery. Undersize lumber may be scant after drying and planing, causing it to be trimmed or downgraded. Oversizing the lumber avoids trimming and downgrading problems, but leads to reduced volume recovery.

For each of the different infeed types, Table 12 indicates average thicknesses, standard deviations within cants, standard deviations between cants, and optimum thicknesses for a 5% scant tolerance. These were based on five measurements: one at each end (6” from the ends) and three at regular intervals along the lengths. Cant thickness averages ranged from 3.825” to 3.890”. For three of the four machines, the combined cutting variation ranged from 0.022” to 0.027”, which is excellent for chipper canters. Only the self-centering strap infeed performed at a lower level, with a combined cutting variation of 0.049” even though the average thickness was relatively low at 3.825”. With this particular infeed, the optimum thickness could have been 0.100” heavier to avoid exceeding the 5% tolerance on scants. With the other infeed types, the cants were slightly oversize. Our analysis of the cants derived from the strap infeed revealed excessive cutting deviations at cant ends. The results shown in Table 13, which exclude end measurements, demonstrate that, on the basis of the three centre measurements, cutting variations were much reduced, and the optimum cutting thickness was a more reasonable 3.843”. The within-cant standard deviation decreased to 0.018” (from 0.044”) when the ends were excluded. This indicated that the self-centering strap infeed had a strong tendency to produce thin ends.

***Table 12 Cant thickness variation based on five measurements per piece***

| Infeed types | Average thickness (in) | S.D. within cant (in) | S.D. betw. cants (in) | Combined S.D. (in) | Optimum thickness (in) |
|---|---|---|---|---|---|
| Self-centering straps | 3.825 | 0.044 | 0.022 | 0.049 | 3.924 |
| Self-centering rollers | 3.877 | 0.020 | 0.010 | 0.022 | 3.779 |
| Translation optimization | 3.890 | 0.024 | 0.014 | 0.027 | 3.804 |
| Translation-alignment optimization | 3.868 | 0.021 | 0.010 | 0.023 | 3.783 |

***Table 13 Cant thickness variation based on three measurements (ends excluded)***

| Infeed types | Average thickness (in) | S.D. within cant (in) | S.D. betw. cants (in) | Combined S.D. (in) | Optimum thickness (in) |
|---|---|---|---|---|---|
| Self-centering straps | 3.832 | 0.018 | 0.016 | 0.024 | 3.843 |
| Self-centering rollers | 3.876 | 0.017 | 0.012 | 0.021 | 3.769 |
| Translation optimization | 3.894 | 0.017 | 0.012 | 0.021 | 3.767 |
| Translation-alignment optimization | 3.872 | 0.015 | 0.010 | 0.018 | 3.752 |

## 6.6 Statistical Analyses

We performed equality tests to verify that (1) the four lots of logs were statistically comparable, and (2) the differentials obtained in mill tests between the four infeed types were statistically significant. We compared the four lots on the basis of value recovery. We used a test for the equality of expectations (two different variances). The detailed results from these equality tests are shown in Appendices I and II.

In essence, equality tests consist of comparisons between two normal distribution curves. The greater the similarity between the two populations in terms of averages and standard deviations, the more they can be deemed to be statistically identical. To compare the two populations, we used two criteria:

- Student’s t-statistic: This criterion is used to determine whether two populations are statistically identical at a given significance level. For example, a t value of between –1.96 and +1.96 indicates that the two populations are identical 9.5 times out of 10 (i.e., 95% of the time), the ±

1.96 values being the lower and upper boundaries of a normal distribution at the 95% probability level.

- Bilateral probability P(T<=t) : This criterion represents the probability of obtaining two identical normal distribution curves when two populations are compared. The higher the value (the closer to 1), the more the results obtained can be deemed to be significantly identical.

### 6.6.1 Equality Tests on Log Sampling

Our first series of equality tests applied to the compared value recoveries calculated from simulations on the four lots of logs. Table 14 displays the values obtained for the t-statistic and bilateral probability (P(T<=t)) criteria. The tests were conducted in such a way as to cover all possible infeed combinations.

The purpose of the six tests we conducted was to confirm that the four lots were statistically identical. All t values were located between –1.96 and +1.96; and the probabilities of obtaining identical results were high, i.e. between 71% and 99%. For example, comparisons between Lot A (self-centering strap infeed) and Lot B (self-centering roller infeed) showed identical results 98.9% of the time. The tests therefore confirmed that log sampling did not privilege any of the infeed systems.

***Table 14 Equality tests on logs***

| | Statistical indicators | Lot A Straps | Lot B Rollers | Lot C Translation optimization |
|---|---|---|---|---|
| Lot B - Rollers | t<br>P(T<=t) | -0.013<br>0.989 | | |
| Lot C - Translation optimization | t<br>P(T<=t) | -0.161<br>0.872 | -0.158<br>0.874 | |
| Lot D - Translation and alignment optimization | t<br>P(T<=t) | -0.357<br>0.722 | -0.371<br>0.711 | -0.164<br>0.870 |

### 6.6.2 Equality Tests on Mill Test Results

The purpose of the second series of equality tests was to confirm whether the results obtained from mill tests for the four infeed types were statistically significant. Table 15 displays the values obtained for the t-statistic and bilateral probability criteria.

The results obtained from our equality tests between the strap infeed and the other three infeed systems confirmed that the differentials observed were significant, as the t values fell outside the ±1.96 boundary range. In addition, the probability of obtaining identical results from this infeed and the other three proved non-existent (0.002, 0.000 and 0.000).

The equality test comparing the self-centering roller infeed and the translation optimized system did not confirm that the value recovery differential between the two was statistically significant. On the other hand, the probability that the two infeeds might yield identical results was only 47.5%.

We got similar results in equality tests comparing the self-centering roller infeed and the optimized systems, or comparing the two optimized systems. Even though the t values fell in-between the boundaries (±1.96), the probabilities that the results might be identical were low (6.7% and 24%). Consequently, we can legitimately state that an infeed involving optimization for translation and alignment will, in most cases, yield greater value recovery than the other infeed types.

***Table 15 Equality tests on cants (mill tests)***

| | Statistical indicators | Lot A Straps | Lot B Rollers | Lot C Translation optimization |
|---|---|---|---|---|
| Lot B - Rollers | t<br>P(T<=t) | -3.191<br>0.002 | | |
| Lot C - Translation optimization | t<br>P(T<=t) | -3.872<br>0.000 | -0.717<br>0.475 | |
| Lot D - Translation and alignment optimization | t<br>P(T<=t) | -4.760<br>0.000 | -1.848<br>0.067 | -1.180<br>0.240 |

# 7 Conclusions

The purpose of this study was to compare canter infeed techniques commonly used in Canadian softwood mills processing small logs. For the purpose of the study, we selected four systems representing different time periods, from self-centering strap devices introduced in the 70s to today's fully optimized systems for translation and alignment.

Theoretical simulations clearly demonstrated the gains achievable with the new optimization techniques as compared to self-centering devices, and mill tests confirmed these trends, although the efficiency levels of 91 to 93% in terms of value recovery were relatively low. Positioning errors associated with rotation and centering were found to have a major impact on performance, as did mechanical damage and excessive cutting variations. Still, the mill tests demonstrated a 5% advantage for the self-centering roller infeed over the strap infeed, 1% for the translation optimized infeed over the roller infeed, and 2% for the translation-alignment optimized infeed over the translation optimized system.

Using simulations, we assessed the effect of rotation errors, and showed that rotation accuracy was much more critical to value recovery with non-optimized infeed devices; rotation errors could lead to a 7% revenue loss, as compared to 1% with a fully optimized infeed. This is due to the fact that, in optimized systems, a second optimization can take place following the rotation process. It is worth noting that, with the four infeed types, the standard deviations on rotation errors were in the order of 30 to 40 degrees, which is high.

Most mill-produced cants showed signs of mechanical damage, irrespective of infeed type. It has already been established that mechanical damage is more likely to result from cutting parameters and knife maintenance than from infeed characteristics. On average, value losses due to mechanical damage ranged from $3 to $16/Mbf, for an average of $11/Mbf. Given that losses in chip value associated with the use of pre-cutting saws was estimated at about $6/Mbf, the use of such saws would have been beneficial with three of the four infeed types as a means of minimizing mechanical damage by the chipper canter.

# 8 References

Allard, F. et Pelletier, M. 1984. Les statistiques : Une nouvelle approche. 453 p.

Laganière, B. 2006. Effects of knife velocity, knife bite and number of knives on lumber surface and chip quality in chipper-canters using bent knives and disposable knives. Forintek Canada Corp.

# Appendix I

## Statistical Equality Tests on Logs

Equality of expectations test: observations from two different variances
Self-centering strap infeed and self-centering roller infeed

| | *Straps* | *Rolls* |
|---|---|---|
| Average | 121.242555 | 121.262708 |
| Variance | 99.11073 | 71.8558957 |
| Observations | 78 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 149 | |
| T-statistic | -0.01349942 | |
| Unilateral P(T<=t)l | 0.4946237 | |
| Critical t (unilateral) value | 1.65514393 | |
| Bilateral P(T<=t) | 0.9892474 | |
| Critical t (bilatéral) value | 1.97601366 | |

Equality of expectations test: obervations from two different variances
Self-centering strap infeed and translation optimized infeed

| | *Straps* | *Optimized* |
|---|---|---|
| Average | 121.242555 | 121.512711 |
| Variance | 99.11073 | 121.27848 |
| Observations | 78 | 79 |
| Assumed average differential | 0 | |
| Degrees of freedom | 154 | |
| T-statistic | -0.16128145 | |
| Unilateral P(T<=t) | 0.43604156 | |
| Critical t (unilateral) value | 1.65480742 | |
| Bilateral P(T<=t) | 0.87208313 | |
| Critical t (bilateral) value | 1.97548616 | |

Equality of expectations test: observations from two different variances
Self-centering strap infeed and fully optimized infeed (translation and alignment

| | *Straps* | *Optimized* |
|---|---|---|
| Average | 121.242555 | 121.76758 |
| Variance | 99.11073 | 67.1034733 |
| Observations | 78 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 148 | |
| T-statistic | -0.35679214 | |
| Unilateral P(T<=t) | 0.3608778 | |
| Critical t (unilateral) value | 1.65521442 | |
| Bilateral P(T<=t) | 0.7217556 | |
| Critical t (bilateral) value | 1.9761228 | |

Equality of expectations test: observations from two different variances
Self-centering roller infeed and translation optimized infeed

| | *Rolls* | *Optimized* |
|---|---|---|
| Average | 121.262708 | 121.512711 |
| Variance | 71.8558957 | 121.27848 |
| Observations | 75 | 79 |
| Assumed average differential | 0 | |
| Degrees of freedom | 146 | |
| T-statistic | -0.15832948 | |
| Unilateral P(T<=t) | 0.43720798 | |
| Critical t (unilateral) value | 1.65535766 | |
| Bilateral P(T<=t) | 0.87441596 | |
| Critical t (bilateral) value | 1.97634563 | |

Equality of expectations test: observations from two different variances
Self-centering roller infeed and fully optimized infeed (translation and alignment

| | *Rolls* | *Optimized* |
|---|---|---|
| Average | 121.262708 | 121.76758 |
| Variance | 71.8558957 | 67.1034733 |
| Observations | 75 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 148 | |
| T-statistic | -0.37091001 | |
| Unilateral P(T<=t) | 0.35561747 | |
| Critical t (unilateral) value | 1.65521442 | |
| Bilateral P(T<=t) | 0.71123493 | |
| Critical t (bilateral) value | 1.9761228 | |

Equality of expectations test: observations from two different variances
Translation optimized infeed and fully optimized infeed (translation and alignment

| | *Optimized* | *Optimized* |
|---|---|---|
| Average | 121.512711 | 121.76758 |
| Variance | 121.27848 | 67.1034733 |
| Observations | 79 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 144 | |
| T-statistic | -0.16350308 | |
| Unilateral P(T<=t) | 0.4351758 | |
| Critical t (unilateral) value | 1.65550318 | |
| Bilateral P(T<=t) | 0.8703516 | |
| Critical t (bilateral) value | 1.97657755 | |

# Appendix II
## Statistical Equality Tests on Cants

Equality of expectations test: observations from two different variances
Self-centering strap infeed and self-centering roller infeed

| | *Straps* | *Rolls* |
|---|---|---|
| Average | 104.2091 | 109.508897 |
| Variance | 116.160204 | 95.2283382 |
| Observations | 78 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 150 | |
| T-statistic | -3.19071335 | |
| Unilateral P(T<=t) | 0.00086432 | |
| Critical t (unilateral) value | 1.65507572 | |
| Bilateral P(T<=t) | 0.00172864 | |
| Critical t (bilateral) value | 1.97590452 | |

Equality of expectations test: observations from two different variances
Self-centering strap infeed and translation optimized infeed

| | *Straps* | *Optimized* |
|---|---|---|
| Average | 104.2091 | 110.653175 |
| Variance | 116.160204 | 101.155045 |
| Observations | 78 | 79 |
| Assumed average differential | 0 | |
| Degrees of freedom | 154 | |
| T-statistic | -3.87209511 | |
| Unilateral P(T<=t) | 7.9546E-05 | |
| Critical (unilateral) t value | 1.65480742 | |
| Bilateral P(T<=t) | 0.00015909 | |
| Critical t (bilateral) value | 1.97548616 | |

Equality of expectations test: observations from two different variances
Self-centering strap infeed and fully optimized infeed (translation and alignment)

| | *Straps* | *Optimized* |
|---|---|---|
| Average | 104.2091 | 112.682699 |
| Variance | 116.160204 | 126.011517 |
| Observations | 78 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 150 | |
| T-statistic | -4.75970744 | |
| Unilateral P(T<=t) | 2.2614E-06 | |
| Critical t (unilateral) value | 1.65507572 | |
| Bilateral P(T<=t) | 4.5227E-06 | |
| Critical t (bilateral) value | 1.97590452 | |

Equality of expectations test: observations from two different variances
Self-centering strap infeed and self-centering roller infeed

| | Rolls | Optimized |
|---|---|---|
| Average | 109.508897 | 110.653175 |
| Variance | 95.2283382 | 101.155045 |
| Observations | 75 | 79 |
| Assumed average differential | 0 | |
| Degrees of freedom | 152 | |
| T-Statistic | -0.71655254 | |
| Unilateral P(T<=t) | 0.23737488 | |
| Critical t (unilateral) value | 1.6549393 | |
| Bilateral P(T<=t) | 0.47474976 | |
| Critical t (bilateral) value | 1.97569534 | |

Equality of expectations test: observations from two different variances
Self-centering strap infeed and translation optimized infeed

| | Rolls | Optimized |
|---|---|---|
| Average | 109.508897 | 112.682699 |
| Variance | 95.2283382 | 126.011517 |
| Observations | 75 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 145 | |
| T-statistic | -1.84790086 | |
| Unilateral P(T<=t) | 0.03332704 | |
| Critical t (unilateral) value | 1.65543042 | |
| Bilateral P(T<=t) | 0.06665408 | |
| Critical t (bilateral) value | 1.97645932 | |

Equality of expectations test: observations from two different variances
Self-centering strap infeed and fully optimized infeed (translation and alignment)

| | Optimized | Optimized |
|---|---|---|
| Average | 110.653175 | 112.682699 |
| Variance | 101.155045 | 126.011517 |
| Observations | 79 | 75 |
| Assumed average differential | 0 | |
| Degrees of freedom | 148 | |
| T-statistic | -1.17951778 | |
| Unilateral P(T<=t) | 0.12004231 | |
| Critical t (unilateral) value | 1.65521442 | |
| Bilateral P(T<=t) bilateral | 0.24008463 | |
| Critical t (bilateral) value | 1.9761228 | |