Technical Note TN-297 December 1999

LOG-LENGTH MEASUREMENT ERRORS WITH SIX SINGLE-GRIP HARVESTER HEADS

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Abstract

Six brands of single-grip harvester head used in eastern Canada were studied working in softwood stands. Considerable variability in the length-measurement errors was observed. Much of the variability could be attributed to the operator, and specifically to the operator's ability to manage the measurement systems and use them correctly. Poorer results were observed where branchiness and stem defects were most pronounced. Under comparable, favorable conditions, all the heads in FERIC's study would be capable of producing logs for which 90% of the lengths would lie within a 10-cm range.

Introduction

Errors in the log lengths produced by single-grip harvester heads are a concern for forestry companies. Logs longer than the prescribed length cause fiber losses during trimming and can lead to blockages that cause expensive downtime at mills, whereas overly short logs can lead to value losses in the production of lumber.

Periodic measurements of log lengths provide an indication of how well the products conform with a client's specifications, but the usefulness of these measurements is limited since they represent an "after the fact" summary. For example, it would be nice to know whether a log was cut too short because the operator chose to eliminate a defect such as a fork, or because of an error by the measurement system.

To identify the factors that lead to variation in log lengths, FERIC has conducted a number of studies since June 1997 to compare the actual lengths of logs with the lengths indicated by the onboard computers of single-grip harvesters that were working in the Acadian and boreal forests. *The objective of the studies was to evaluate the machines in normal use under the conditions that prevailed during FERIC's visit. The results should thus not be used to compare the merits of the various brands of head*. The companies that participated in the trial were Scieries Saguenay Ltée, Produits Forestiers Labrieville, and Coopérative Laterrière in Quebec; J.D. Irving, Limited, in New Brunswick; and Mactara Limited and Stora Enso Port Hawkesbury Ltd. in Nova Scotia. FERIC's Western Division has also performed similar studies of the equipment used in western Canada for the species in that region (Andersson and Plamondon 1999).

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KEYWORDS: Tree-length systems, Softwoods, Log length, Measurement systems, Single-grip harvesters, Harvester heads, Keto 500, Logmax G50, Logmax 750, Rottne EGS, Silvatec 445, Silvatec 555, Timberjack 762B, Timberjack 762C, Valmet 960.

Because the operating and maintenance conditions could differ greatly between the studies, the current report provides the results for brands of heads that had been the subject of at least two studies in softwood stands. These heads were the Keto 500, Logmax 650 or 750, Rottne EGS, Silvatec 445 or 555, Timberjack 762B (and C), and Valmet 960.

Study Method

For a series of trees chosen at random, the dimensions of logs produced according to the onboard computer's settings were recorded by an observer in the machine. The operator arranged the logs on the ground in the order they were processed so their lengths could subsequently be measured. The target sample size was 100 logs per study, and in addition to length, the characteristics of each log, its defects, and any conditions likely to lead to measurement inaccuracies were recorded. The operator's productivity level was not considered to be a factor in determining the accuracy of length measurements during the study; operator working speeds were comparable to those in normal operations, or a bit slower.

The operators were informed of the goals of the study. Those who were used to calibrating their machines did so, whereas others relied on the parameters already programmed into the computers at the time of the study. Several operators were unfamiliar with the calibration procedures, which were the responsibility of another operator or of the contractor. *It is thus possible that certain results could be attributed to poor calibration of the measuring system.*

Descriptions of the Equipment Studied

Table 1 lists the heads studied on the operations of the companies that participated in FERIC's project. All the studies, with the exception of those performed on Mactara Limited's operations, were conducted at temperatures above freezing. The temperatures remained roughly constant during each study; thus, temperature was not a factor that could have affected the degree of variability within a given study.

The onboard computers responsible for measurement of the log lengths were the models normally provided by equipment dealers in the Canadian market. The following systems were used in FERIC's study: the Scanmat system for the Keto heads; a proprietary system by Grangärde Maskin, the manufacturer of the Logmax heads; the System 90 for the Rottne heads; the Silvatec system for that company's heads; the Lokomatic 90 for the first two Timberjack studies and the 3000 system for the study conducted at Scieries Saguenay Ltée; and Valmet's VMM 1000 system.

Table 1. Equipment (head and carrier) studied

	Period	Head					
		Keto 500	Logmax 650 and 750	Rottne EGS	Silvatec 445 and 555	Timberjack 762 B and C	Valmet 960
Company							
Coopérative Laterrière	July 1997	Timbco T-445 (Keto 1)					
J.D. Irving, Limited	October 1997	John Deere 690 ELC (Keto 2)		Rottne 4 cyl. (Rottne 1)			Valmet 901 (Valmet 1)
Mactara Limited	February 1998		Logmax 750 Caterpillar 320 (Logmax 1)			762B, Timberjack 608 (Timberjack 1)	
Produits Forestiers Labrieville	October 1997					762B, Timberjack 1270 (Timberjack 2)	
Stora Enso Port Hawkesbury Ltd.	October 1998		Logmax 650 Timberjack 608 (Logmax 2)	Rottne 4 cyl. (Rottne 2)	Silvatec 445, Hyundaï 200 (Silvatec 1)		
Scieries Saguenay Ltée	October 1998				Silvatec 555, Cat 320L (Silvatec 2)	762C, Timberjack 1270B (Timberjack 3)	Valmet 911C (Valmet 2)

Results and Analysis

For a given study, the frequency distribution for the differences between the actual length and the length estimated by the onboard computer typically followed a normal distribution. Figure 1 provides an example of the distributions obtained for two studies with visibly different results, even though both were achieved with the same model of harvester head.

The distribution in situation A is centered on a value of 0 and clusters relatively tightly around that value, whereas the distribution in situation B is much wider and has a positive bias (i.e., the logs were generally longer than the computer indicated). The mean and standard deviation of the “actual minus computer” differences are thus two obvious indicators of a harvester head’s length-measurement performance. The mean provides an indication of good or deficient calibration, and problems related thereto are generally easy to correct. However, the standard deviation represents a non-systematic error that is more significant and more difficult to correct, since it can be attributable to several factors.

Figure 2 summarizes the results in the form of a box plot, with individual boxes for each study. Each box represents a range that contains 50% of the observations, and the upper and lower horizontal tabs represent a range that contains 80% of the observations. The length error, expressed along the vertical axis, provides an indication of the extent of the bias in each study. The two studies in Figure 1 are found in Figure 2 under the headings Timberjack 1 and Timberjack 2.

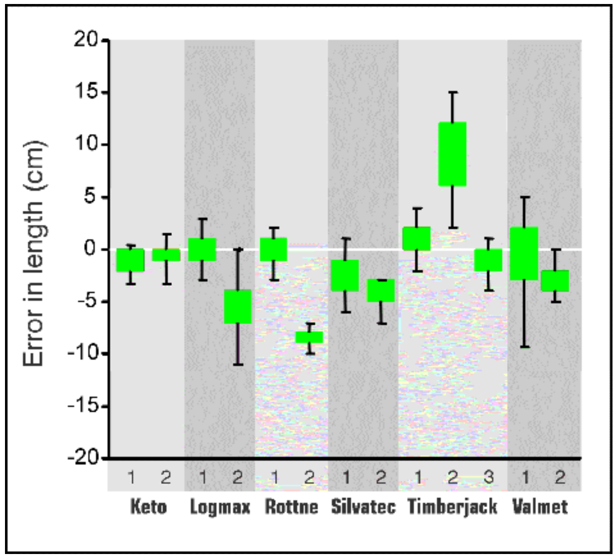

Figure 2. Distribution of errors in length for each study.

It’s not surprising that the results that showed little bias (e.g., the Keto 1, Logmax 1, Rottne 1, and Valmet 1 studies) were generally produced by machines whose operators were familiar with the calibration procedure. However, the measurement of bias is not always a direct indication of the conformity of the products with client specifications. For example, some contractors adjust log lengths by modifying the limiting values for the “bucking window” (i.e., the values that the computer uses to determine when to cut a log) rather than by calibrating the system. This was the case, for example, in the Rottne 2 study, which produced a mean

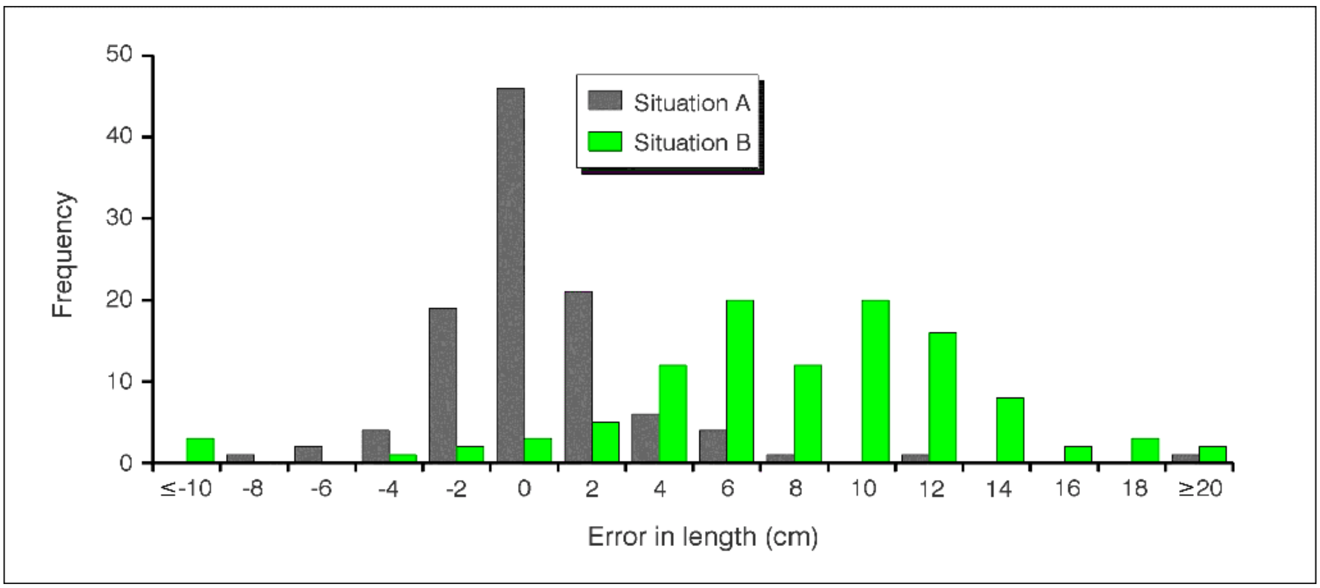

Figure 1. Frequency distribution for the differences between the actual measurement and the length indicated by the computer.

negative bias of 8.75 cm but nonetheless provided good conformity with the desired products as a result of using an equivalent bias for the bucking window.

Table 2 presents the means (bias) and standard deviations (precision) of the errors obtained for the logs from the 13 studies, with all products combined. Three classes of standard deviation (σ) were apparent:

A σ<4 cm:
Rottne 2, Silvatec 2, Timberjack 1 and 3, Valmet 2

B 4<σ<7 cm:
Keto 1 and 2, Logmax 1, Rottne 1, Timberjack 2

C σ>7 cm:
Logmax 2, Silvatec 1, Valmet 1

Table 2. Summary statistics for the length errors in each study

	Mean (cm)	Standard deviation (cm)	Number of logs
Study			
Keto 1	–0.33	7.00	61
2	–1.54	6.91	151
Logmax 1	–0.77	6.01	70
2	–5.06	8.41	107
Rottne 1	–0.55	5.17	112
2	–8.75	1.28	44
Silvatec 1	–1.63	10.05	125
2	–4.24	2.05	102
Timberjack 1	1.05	3.64	106
2	8.44	6.21	108
3	–1.48	2.07	103
Valmet 1	–0.48	13.13	93
2	–2.74	2.12	109

Group C combines two studies performed under the least favorable stand conditions in terms of branchiness. The Logmax 2 and Valmet 1 studies were performed in the Acadian forest, and although the branch diameters were generally less than 3 cm, branches were nonetheless abundant over a large portion of the stems.

The other studies were conducted with less-branchy trees. It's interesting to note that Group A comprised three studies conducted with Scieries Saguenay Ltée, the company that had the most comprehensive quality-control program for log lengths.

Effect of Log Size and Volume

The assumption that the length error increases as log length increases cannot fully explain the variation observed in the results. This assumption would hold true in the case of a systematic bias. If, for example, the measuring system overestimates lengths by a factor of 1%, the absolute length error will obviously increase for longer logs. However, this effect, although probably real, remains weak by comparison with other sources of variation, and would be easy to eliminate with proper calibration.

Figure 3 presents the observed errors as a function of log volume. Although the errors tended to be comparable in magnitude for logs of 0.1 m³ and larger, the graph shows that the largest errors actually occur below this threshold. It is thus the smallest diameters that are most likely to generate large errors, perhaps due to the difficulty of maintaining good contact between the measuring wheel and the surface of a small log.

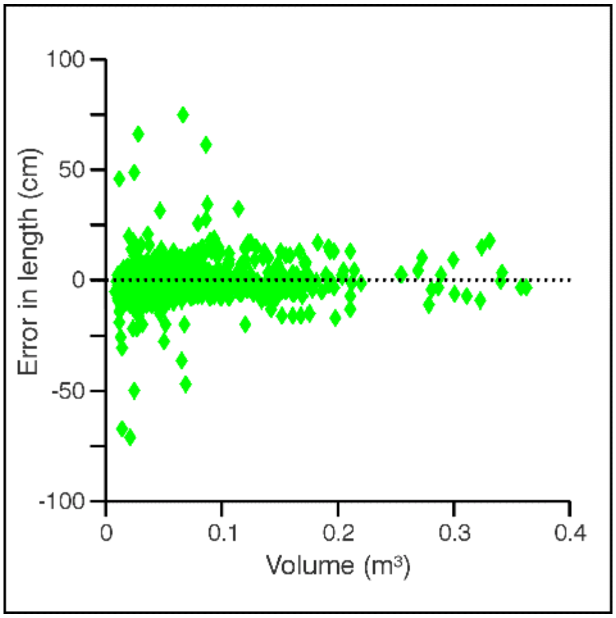

Figure 3. Length errors as a function of log volume for all the heads.

For the distribution of errors as a whole, the "cloud" of data points formed by the observations was generally symmetric around a horizontal line, with the errors distributed roughly equally around this mean. However, the Keto 2 study was an exception, since the errors with small diameter classes in that study had a clear negative bias. This phenomenon can probably be attributed to a specific characteristic of the harvester head. Whereas all the other heads, including the one in the Keto 1 study, were equipped with a measuring wheel for encoding lengths, the head in the Keto 2 study measured lengths by the rotation of its feed tracks. This means that any rotation of the tracks, even with the head empty, increased the length value displayed by the computer. The operator should watch for this condition and stop the feed tracks immediately when slippage occurs to avoid overestimating lengths and producing too-short logs.

Effect of Species

Species differences are sometimes invoked to explain differences in error levels. For example, it is sometimes assumed that the lengths of fir logs, which have softer bark than spruce, would be systematically underestimated. The results of FERIC's studies neither confirmed nor invalidated this hypothesis because the homogeneous species composition within each study did not permit such a comparison. It is nonetheless probable that the magnitude of any such effect would be low, and that other factors would have greater importance.

Effect of Defects

Regrouping the observations for logs that included defects such as scars, calluses, knots with a diameter greater than 3 cm, very knotty sections, and dry or crooked trees, increased the standard deviation of the length-measurement errors by 45% compared with that of logs free of such defects. However, the presence of such defects does not inevitably increase measurement errors; for example, a scar may not lie in the path of the measuring wheel, and would thus have no effect.

"Zeroing"

"Zeroing" (resetting the length measurement) is generally necessary whenever a tree slips out of the harvester head or after a particularly difficult delimbing sequence. Operators typically reset the length-measurement device by activating the saw once the butt of the tree is aligned with it. If the saw cut doesn't actually touch the tree, the process almost always results in a large error even if the error appears minimal from the harvester's cab. However, operators have little room to maneuver, because they are not permitted to cut off large disks from the stem. The Logmax computer is the only one among those studied that permits zeroing of the measurement wheel without activating the saw.

Other Factors

Several other large errors cannot be explained based on FERIC's observations. It is possible that the opening and closing of the head's delimbing knives or various parameters related to the head design (e.g., the allowable displacement of the measuring wheel and the length of the head) could play a role; however, these assumptions could not be verified using the experimental design in this study. Additional factors, including dynamic parameters such as the acceleration and deceleration rates of the feed rollers, were also not assessed.

Conclusions

It's often difficult to identify a single factor in the machine-human-resource combination that is solely responsible for a given result, and this study was no exception. Despite the variability among the machines and study conditions, the study demonstrated that the six brands of harvester heads are all capable of providing reasonable measurement accuracy. Situations with highly branchy fir or spruce in the Acadian forest partially explained some of the poorer results. Physical defects of trees and logs also tended to increase the size of the errors, but did not explain all the errors. Insufficient knowledge of the calibration procedure by some operators, and clues such as the absence of even a simple tape measure on the machine, tend to suggest that human factors were an important source of errors. For this reason, adequately training all operators on how to adjust and calibrate their machine's measuring systems appears to be an essential first step in the implementation of any program intended to improve the quality of log-length measurements.

Attention should also be paid to programming suitable limits for the bucking window to match the client's tolerances. For example, consider a client who requires sawlogs with lengths between 5.00 and 5.10 m, and assume that these values are directly programmed into the onboard computer as the bucking window. If ten logs are produced at the lower limit (5.00 m), it is likely that five will be outside the range specified by the client. To provide a greater margin for error, it would be preferable to program a bucking window narrower than the standards for the desired products. However, an overly narrow bucking window would slow the head's work.

The fact that three of the best results were observed on the same company's operations suggests that ongoing monitoring of bucking quality *in situ* will provide good results. Incentives such as quality bonuses at the end of the year and penalties such as fines for logs that would be likely to cause interruptions at the mill could help make contractors and their machine operators more aware of the consequences of their actions. The dispersion of operations and the demands of multiple clients for different products can, however, increase the cost of such practices. For these reasons, some managers prefer centralized slashing and the use of full-tree harvest systems. The results of a comparative study (Favreau and Corneau 1998) demonstrated, among other things, that the slashing of full trees at the mill's infeed deck is also not free of errors. In that study, the distribution of log lengths produced by the single-grip harvester was similar to those obtained in the present study.

Various measurements of a system's performance can be used. The bias and the standard deviation of the errors provide an indication of the "intrinsic" precision of the systems under specific conditions, but provide little information on product conformity with client specifications. Because the tolerances often vary from one operation to another, the percentage of compliant products doesn't provide a suitable means of comparison between operations. Sondell (1995) proposed an alternative based on the concept of a group of "the best five" (the five most-representative adjacent classes); this approach sums up the proportion of products that fall within a 5-cm range, and in Sondell's study, the proportion that fell within that range varied between 68 and 89%. A group of the 10 most representative adjacent classes could be suitable for use in the Canadian context (Andersson and Plamondon 1999), and the systems in the present study would all have been capable of producing nearly 90% of logs within these classes.

This project also permitted the first observations in eastern Canada of the new generation of onboard computers (e.g., the Timberjack 3000). These new systems are common in northern Europe (Sondell 1995), where operators take advantage of the system's ability to optimize the bucking of stems. However, the accuracy in length measurement obtained with the new system was no better than that obtained with the Lokomatic 90 (in the Timberjack 1 study), which until recently has been used on most Timberjack machines in Canada. This suggests that the power of the new systems lies more in their ability to analyze data than in any improved length-measurement accuracy.

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