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SORTING FOR QUALITY WITH A CUT-TO-LENGTH SYSTEM

J.-F. Gingras, F.E.* and A. Godin**

Abstract

This study compared the productivity, cost and efficiency of a single-grip harvester and a shortwood forwarder for sorting pulpwood. Three methods were analyzed: in the first, two pulpwood grades were separated by the forwarder; in the second, this separation was conducted by the harvester; and in the third, the harvester did a three-way pulpwood sort (for grade and species).

Introduction

Gingras (1996) reported that little or no productivity loss should be expected when separating up to four products with single-grip harvesters based on size or species criteria. Stora Port Hawkesbury Ltd. (Port Hawkesbury, N.S.) asked FERIC to assess the productivity of harvesters and forwarders required to sort products based on quality specifications rather than based on size or species differences. In November 1996, FERIC studied Thomas F. Hayne Contracting Ltd. cut-to-length operation south of New Glasgow (N.S.). The shortwood machines observed were a 1992 Rottne single-grip harvester and a 1995 16-tonne Rottne SMV eight-wheeled forwarder (Figure 1).

Figure 1. The Rottne harvester and forwarder used in the sorting trials.

Context

Stora has traditionally segregated its pulpwood supply (2.44-m bolts) into two categories, the higher-quality Grade 1 destined for the groundwood/newsprint line and the lower-quality Grade 2 destined for the sulfite pulp process. The general specifications for the two grades are as follows:

* Jean-François Gingras is Group Supervisor, Wood Harvesting, Eastern Division.

** Alyre Godin is a Technician, Wood Harvesting, Eastern Division.

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- **Grade 1** (GR1): sound spruce and fir, fresh wood (no soft rot); straight, well-delimbed bolts.
- **Grade 2** (GR2): bolts of all species, some soft rot allowed (max. 20%), as well as more tolerance to size and form defects.

The difficulty associated with grade sorting during mechanized shortwood harvesting is that whereas some defects are easy to detect (undersize bolts, external defects, poor form), many of the internal defects related to rot can only be seen from the bolt ends, which are not clearly visible to the harvester operator during processing.

To date, most of Stora's mechanized contractors have been segregating the GR1 from the GR2 bolts using the forwarder, under the assumption that sorting is most cost-effective when done with the lowest-cost machine. During loading, the forwarder operator can see the bolt ends and decide whether the grapple load is GR 1 or GR 2.

The objective of this study was to verify the hypothesis that even though the harvester is the higher-cost machine, the limited impact of sorting on its productivity would result in lower overall cost increases than by using only the forwarder to separate the products. Three sorting scenarios were tested. The first two methods were used to identify which machine was best suited for the grade sort, and the third introduced a more elaborate sort for experimental purposes:

- **Method 1:** No grade-based sorting was performed by the harvester, and the forwarder operator separated the GR1 and GR2 bolts during loading.
- **Method 2:** The harvester operator separated bolts into GR1 and GR2 piles, and the forwarder operator kept the piles separate in his front and back bunks.
- **Method 3:** The harvester operator separated the GR1 fir, the GR1 spruce, and the GR2 pulpwood (all species) into three piles. The forwarder operator kept the GR1 species separated in his front and back bunks, then made separate trips to collect the GR2 bolts.

A few sawlogs and hardwoods were also sorted separately, giving a total of four sorted products with methods 1 and 2, and five with method 3.

To eliminate the "learning curve" effect, which can often bias results with newly introduced working methods, both operators had tried grade-based product sorting in the weeks prior to the actual trial. The two operators were experienced and participated enthusiastically in the trials. The sorting methods were used sequentially in alternating strips to provide replication and to reduce the impact of differences in stand and terrain conditions. The blocks were only harvested during day shifts.

Results

Harvester

The productivity and cost results obtained with the harvester are presented in Table 1, based on the machine costing assumptions given in the Appendix. The costs represent only direct costs, with no provision for supervision, overhead, profit, etc. To eliminate the variations induced by variable proportions of sawlogs, the figures reported are based only on cycles in which pulpwood was produced.

Adding a two-way GR1 and GR2 sort caused a slight (4.0%) increase in harvester cycle time per tree. This decrease in productivity resulted from longer pro-

Table 1. Impact of sorting on harvester productivity (pulpwood only)

	Method 1 (sorting by forwarder)	Method 2 (sorting by harvester, GR1/GR2 sort)	Method 3 (sorting by harvester, GR1 fir/GR1 spruce/ GR2 all species)
Total PMH studied	4.2	8.1	4.6
Total cycle time (min/tree)	0.574	0.629	0.661
Effect of sorting			
Time for processing and for arranging piles (min/tree)	0.238	0.261	0.278
Net difference compared with method 1 (%)[a]	n.a.	+4.0	+7.1
Harvesting cost			
Machine (new) hourly cost ($/PMH)	115.00	115.00	115.00
Wood cost ($/m³)[b]	12.43	12.95	13.37

[a] Difference in processing time pro-rated over total cycle time.
[b] Based on the productivity of method 1 @ 9.25 m³/PMH.

cessing times due to the operator trying to decide on quality classes and when positioning additional piles on the ground. There was an additional drop in productivity when going to a three-way GR1 fir/GR1 spruce/GR2 sort.

In areas with dense undergrowth, as in the present study, the impact of sorting on harvester productivity depends largely on the ease of creating separate piles, because the regeneration and underbrush hamper head and boom movement. Although it may be possible to position products at different angles on the ground by turning the head slightly, this is also influenced by the amount of regeneration and underbrush present.

From habit, the harvester operator processed only to one side of the machine, and this led to large volumes concentrated in a single wood "sidewalk", which made it difficult to identify separate product piles (Figure 2). Processing to both sides of the machine would have provided more room for piles without affecting the productivity of the harvester or the forwarder.

Figure 2. Processing on only a single side formed a wood "sidewalk" that made it difficult for the forwarder operator to separate GR1 and GR2 piles.

Forwarder

The productivities and cost calculations for the forwarder are presented in Table 2. The most productive method was to forward pulpwood sorted by the harvester into two categories, placing one product in the front bunk and the other in the back bunk. Loading time was shorter with the two-way harvester sort than when no pulpwood sort had been conducted by the harvester. Once at the landing (Figure 3), unloading time was not significantly affected by the sorting method used on the cutover.

Table 2. Impact of sorting on forwarder productivity

	Method 1 (sorting by forwarder)	Method 2 (sorting by harvester, GR1/GR2 sort)[a]	Method 3 (sorting by harvester, GR1 fir/GR1 spruce/ GR2 all species)[a]
Total PMH	2.8	3.7	3.0
Average forwarding distance (m)	270	350	330
Volume/PMH (m^3)	16.2	16.7	17.4
Effect of sorting			
Loading productivity (bolts/min)	12.4	15.7	12.7
Unloading productivity (bolts/min)	38.0	40.3	39.0
Adjusted productivity[b] (m^3/PMH)	15.8	17.6	16.1
Productivity gain compared with method 1 (%)	n.a.	+11.4	+1.9
Forwarding costs			
Machine (new) hourly cost ($/PMH)	91.30	91.30	91.30
Wood cost ($/$m^3$)	5.78	5.19	5.66

[a] Products were kept separate in the forwarder bunks and were unloaded separately.
[b] Standardized distance (300 m) and payload (15.7 m^3).

Figure 3. Separate unloading of GR1 (right) and GR2 (left) bolts.

Forwarding three pulpwood products was more problematic because the operator did not know in advance how much bunk space would be needed for each product. This would be less of an issue in operations where large amounts of processed wood are on the ground ahead of the forwarding phase. During the study, the GR1 and GR2 sorts were forwarded in separate trips in method 3.

It was observed that snow cover can cause problems in differentiating piles based on species or even on grades when bolt size is not a contributing factor.

Quality of Sorting

An assessment of the quality of sorting was conducted from samples of the GR1 and GR2 piles taken at the landing (Table 3). Sorting with the harvester reduced the proportions of bolts in the wrong pile; the proportion of GR1 bolts in the wrong pile decreased from 45% to 33%, and the proportion of GR2 bolts in the wrong pile decreased from 18% to 12%. The reader should note that the percentages presented relate to bolt numbers and not to volumes. Since a large pro- portion of the GR2 bolts present in the GR1 pile were undersized bolts, the actual volume of misplaced mate- rial was much lower than these percentages suggest.

The acceptable rot threshold is a subjective assessment and could vary with different observers. The same FERIC researcher conducted all assessments during these trials, so the *relative* proportions should be representative. Figure 4 illustrates examples of GR1 and GR2 bolts in the wrong piles.

In the case of the harvester sort, the forwarder operator also refined the sort somewhat during loading to correct the harvester operator's mistakes.

The difference in quality between the two-way and the three-way pulpwood sorts can be explained by the higher proportion of spruce in the strips harvested with the latter method. Spruce normally contains less rot and stain than balsam fir, and thus is more easily separated than fir.

Table 3. Sorting quality in the piles at the landing

	Method 1 (sorting by forwarder)	Method 2 (sorting by harvester, GR1/GR2 sort)	Method 3 (sorting by harvester, GR1 fir/GR1 spruce/ GR2 all species)
GR1 bolts in the wrong pile (% of bolts)	44.7	32.7	24.3
GR2 bolts in the wrong pile (% of bolts)	18.4	12.6	12.0
Rot	7.6	4.2	2.3
Undersize (<9 cm inside-bark diameter)	6.4	4.3	6.4
Dead	0.3	0.7	0.8
Non-circular form, excessive flare	2.1	1.7	2.2
Serious breakage	0.0	0.2	0.0
Excessive limbs, knots	1.4	0.9	0.0
Bark intrusions in scars/splits	0.6	0.6	0.3

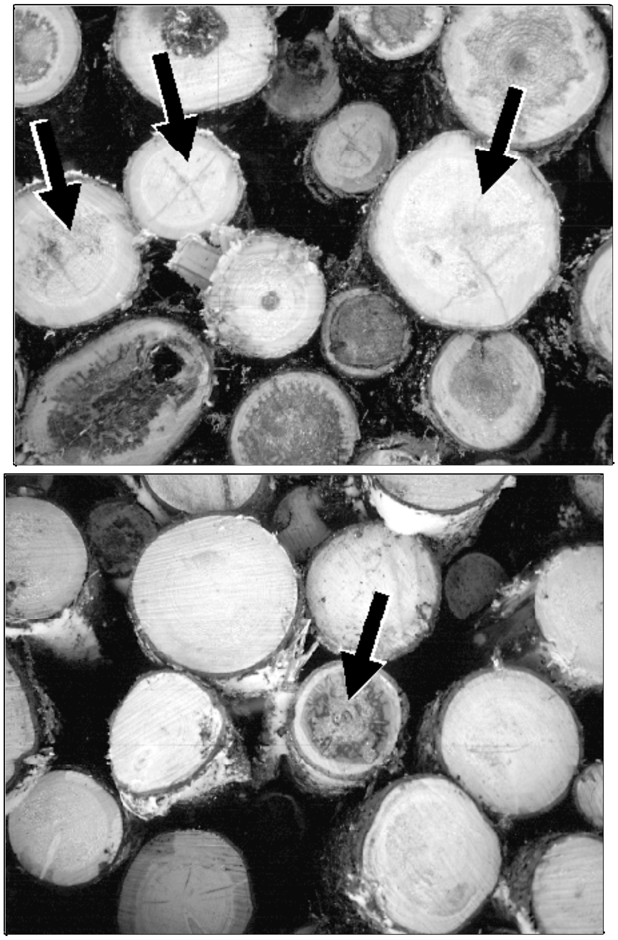

Figure 4. Example of GR1 bolts in GR2 pile (top) and GR2 bolts in the GR1 pile (bottom).

Discussion

The total direct system cost with the three sorting methods was calculated (Table 4). Different machine costing assumptions, such as using a used harvester or a lower-cost forwarder, could lead to different or more significant cost differences between scenarios.

For two pulpwood products, there was no major difference in total wood costs between sorting with the harvester and sorting with the forwarder. The slight losses in harvester productivity when sorting were offset by the gains in forwarder loading productivity, and this made method 2 the lowest-cost scenario. Although the cost differences were small, the sorting quality improved substantially when the harvester did the initial separation; the proportion of GR1 bolts in the wrong pile decreased by 12 percentage points, and the proportion of GR2 bolts in the wrong pile decreased by 6 percentage points.

A three-product sort for pulpwood (in addition to sawlogs and hardwoods) was feasible for the harvester, although this resulted in higher productivity losses than with a two-product sort. However, because of higher forwarding costs, the three-product sort increased the total cost by about $0.89/m³ compared with a two-product sort.

Forwarding was more difficult with three separate pulp products than with two because the exact quantities of each product in a given strip were unknown, thereby making it difficult for the operator to allocate forwarder bunk space. Modified bunk configurations might be considered, such as using a central vertical picket to provide a right-left separation. One could also consider transverse loading by moving the 8 external pickets in by 10 to 15 cm, thus providing three transverse loading pockets.

During the study, it was observed that it can be difficult for the forwarder operator to differentiate closely spaced or snow-covered log piles. If the harvester operator had decked to both sides of the machine, the piles would have been more distinct. Alternatively, several harvester head manufacturers (e.g., Keto, Rottne, Lako, Timberjack) offer an option for applying paint to the log's end during processing to facilitate log identification. One Swedish company (Droppen) offers a retrofit system for existing heads. This approach could be used to mark GR1 and GR2 bolts (or spruce and fir bolts) differently.

Table 4. Total system cost with the three sorting methods

	Method 1 (sorting by forwarder)	Method 2 (sorting by harvester, GR1/GR2 sort)	Method 3 (sorting by harvester, GR1 fir/GR1 spruce/ GR2 all species)
Harvesting cost ($/m³)	12.43	12.95	13.37
Forwarding cost ($/m³)	5.78	5.19	5.66
Total cost ($/m³)	18.21	18.14	19.03

Reduced visibility during night shifts or rainy weather hampers the sorting function. Lights from the harvester create shadows that make it difficult to identify whether a pile of bolts is GR1 or GR2. Generally, the harvester is best suited for sorting by species, external defects and size. It is not as effective with grade sorts based on internal defects such as stain or rot because the operator cannot easily see the ends during normal processing operations. Therefore, in all cases, some sorting responsibility should remain with the forwarder operator to correct any harvester operator's mistakes or to enhance separation based on rot or other internal defects.

Conclusions

Under the study conditions, it was preferable to conduct an initial grade sort with the harvester rather than relying solely on the forwarder. This approach slightly reduced the total cost and it improved the quality of the sorting function. Nonetheless, because of the inherent difficulty harvester operators face in clearly seeing the log ends during processing, the forwarder operator should still have some responsibility for enhancing the sort during the loading and unloading phases.

From a technical perspective, paint-application systems mounted on the harvester heads could be considered as a tool to facilitate the identification of different categories of piles (e.g., species or grades). Physical changes to forwarder bunk configurations could also be considered to facilitate product separation during the forwarding cycle.

References

Gingras, J.-F. 1996. The cost of product sorting during harvesting. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Tech. Note TN-245. 12 p.

Appendix Machine Costing Assumptions

	Rottne harvester	Rottne forwarder
Inputs		
Expected machine life (years)	5	5
Scheduled machine hours (SMH)/year	3 600	3 600
Purchase price ($)	515 000	380 000
Salvage value ($)	51 500	38 000
License and insurance ($/year)	25 750	19 000
Interest rate (%)	8	8
Utilization (%)	85	85
Lifetime repair costs ($)	515 000	380 000
Fuel consumption (L/PMH)	18	15
Fuel price ($/L)	0.45	0.45
Oils and lubricants ($/PMH)	2.00	1.00
Operator wages ($/SMH)	20.00	20.00
Fixed costs ($)		
Cost per PMH	47.70	35.19
Cost per SMH	40.54	29.93
Variable costs ($)		
Cost per PMH	43.76	32.57
Cost per SMH	37.20	27.70
Labor costs ($)		
Cost per PMH	23.54	23.54
Cost per SMH	20.00	20.00
Total costs ($)		
Grand total per PMH	115.00	91.30
Grand total per SMH	97.74	77.63