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CHAIN FLAIL DELIMBER-DEBARKERS IN EASTERN CANADA: A PRELIMINARY ASSESSMENT

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Abstract

As of the beginning of 1990, there were a number of commercial models of chain flail delimber-debarkers available in North America, and several prototypes were either operational or under development. Preliminary results are presented of FERIC studies on the productivity and performance of two commercial chain flail delimber-debarkers. The units studied were the Forest Pro model 23, and the Peterson-Pacific DDC 5000.

Introduction

Skidder-mounted chain flails were used extensively as multi-stem delimbers during the 1970's. The recent introduction of double-drum flails has dramatically increased the delimbing and *debarking* ability of this technology, resulting in a resurgence in interest in the concept throughout Canada. This interest has been largely in response to the need to maximize fibre supply and value from the forest resource, as well as supplementing current woodroom capacity. Stationary and mobile chain flail delimber-debarkers can augment economic utilization of hardwoods and small stems because they are relatively insensitive to tree size and form. Therefore, they offer the potential for increasing stand utilization in low-quality stands and for increasing overall fibre recovery efficiency.

In early 1990, there were seven double-drum flail operations in eastern Canada. This report presents preliminary results of FERIC studies of three of these satellite chipping operations. Flail models studied were the Forest Pro model 23 delimber-debarker at Valley Forest Products in New Brunswick, and the Peterson-Pacific DDC 5000 delimber-debarker-chippers at Scott Maritimes Ltd. in Nova Scotia and at Technologic Timber Ltd. in Armstrong, Ontario.

The objectives of the report are to present a *first assessment* of the productivity, advantages, disadvantages, operational implications and suitability to Canadian conditions of this technology. This work will be followed in 1991 by a thorough economic analysis of in-woods chipping and satellite woodroom alternatives based on the double-drum chain flail technology.

Study Methods

A shift-level availability and productivity study of the Forest Pro delimber-debarker was compiled using data from daily vibration recorder charts and weigh scale tickets. For the Peterson-Pacific units, short-term continuous time studies were undertaken. Work sampling techniques were also used to determine the interactions between the various components of the full-tree flail/chipping operations.

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Company-supplied records of chip van payloads and chip sampling results were used throughout the studies. All productivity results are presented in oven-dry tonnes (odt) per productive machine hour (PMH), or if the moisture content of chips was not available, in green tonnes per PMH. It should be remembered that the results are specific to the operating conditions encountered during the studies and the sampling techniques used.

Forest Pro Model 23 Delimber-Debarker

The Forest Pro model 23 chain flail *delimber-debarker* is manufactured by Forest Processing Equipment Inc. of Shreveport, Louisiana. It consists of a hydraulically-driven horizontal double-drum flail, mounted on a heavy-duty frame having a tandem-axle suspension. Each flail drum has 72 lengths of chain and the rotation speed is variable from 600 to 650 rpm. The flail is driven by a 317-kW Caterpillar 3406 diesel engine. The infeed opening measures 61 cm high and 122 cm wide, providing for a maximum tree capacity of about 58 cm in butt diameter. The variable infeed rate ranges from 21 to 49 m/min. Debris removal is via a conveyor out the side of the machine. The flail unit has a fifth-wheel attachment and a converter dolly is hooked to the unit to enable towing it from site to site. The Forest Pro studied had been modified with the addition of a Rotobec 150C knuckleboom loader. The overall weight of the machine studied, including the loader, was 21.8 tonnes (Figure 1). Excluding the cab and loader, the machine costs approximately C$210 000 F.O.B. Shreveport, LA.

The machine was studied on the operations of Valley Forest Products Ltd., the woodlands subsidiary of St.Anne-Nackawic Pulp & Paper Company Ltd., in Nackawic, New Brunswick. The harvesting system consisted of the Forest Pro flail operating in conjunction with a Morbark model 27 Chiparvestor. Two Koehring KFF feller-forwarders supplied full-tree hardwoods to the flail.

Figure 1. Forest Pro model 23 delimber-debarker.

Performance

The company reported that the productivity of the Forest Pro during early trials between January and May 1989 ranged from 28.8 green tonnes (mgt) per productive machine hour (PMH) to 32.2 mgt/PMH [2]. Mechanical availability improved from 60% to 68% during this period after some modifications were made to adapt the machine for better operation in hardwood conditions.

In the summer of 1989, shift-level data on the Forest Pro delimber-debarker were collected by Valley Forest Products from July 4th to August 20th for analysis by FERIC. In addition, work activity sampling was conducted periodically over the 33 shifts monitored. During this period, the Forest Pro flail operated in a full-tree hot logging operation harvesting mainly maple and beech species. Tree size averaged 0.18 m^3/tree.

During the study, flail productivity averaged 31.4 mgt/PMH or 19.1 oven-dry tonnes per PMH (Table 1). Productivity peaked at 34.5 mgt/PMH (21.0 odt/PMH), over a one-week period in August 1989. It was observed that the processing rate of the flail was influenced by tree size; in general, the larger the tree size, the slower the processing rate. However, because of the larger stem volume, productivity in green tonnes per PMH increased as tree size increased (Figure 2). Mechanical availability and utilization showed further improvement from the earlier trials of the Forest Pro, with results of 78% and 70% respectively.

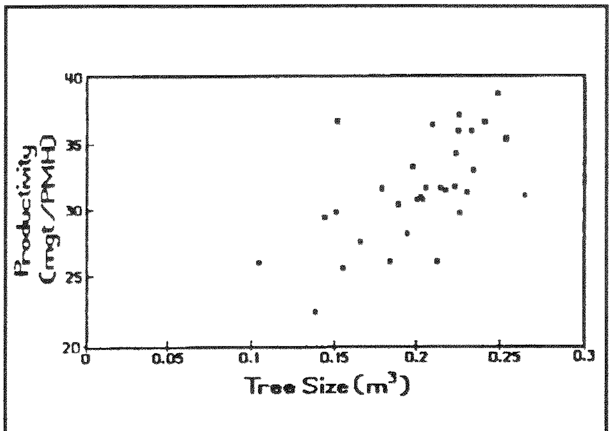

Figure 2. Forest Pro productivity versus tree size.

Table 1. Forest Pro shift-level study summary; (Hardwood; July-August 1989)

Length of study (shifts)	33
Average tree volume (m^3)	0.18
Green tonnes per PMH	31.4
Oven-dry tonnes per PMH	19.1
Trees per PMH	160
Mechanical Availability[1] (%)	77.8
CPPA Availability[2] (%)	80.0
Machine Utilization[3] (%)	70.2

[1] Mechanical availability = $\frac{\text{PMH}}{\text{PMH + Repairs + Service}}$

[2] CPPA availability = $\frac{\text{SMH - (Repair + Service + Wait for Repair)}}{\text{SMH}}$

[3] Machine utilization = $\frac{\text{PMH}}{\text{SMH}}$

Activity sampling results from the Forest Pro study are given in Table 2. The delays associated to the Koehring KFF (4.8%) were caused by the machine unloading and maneuvering close to the flails. With two feller-forwarders supplying the material, there was rarely a shortage of trees at the landing. The loader-related delays (14.2%) resulted from clearing debris and personal delays.

Table 2. Distribution of Forest Pro work activity (n = 3136 observations)

Activity	% of total time
Productive time	70.2
Wait for KFF	4.8
Wait for on-loader	14.2
Wait for chipper	5.0
Position/change vans	2.0
Clean-up skidder interference	0.9
Mechanical delays	2.9
Total time	100.0

During the monitoring period, 97 van loads were sampled and analysed by the company. Bark content of the chips averaged 2.5% before screening and 2.0% after screening. This was the best result to date obtained by the company, and probably resulted from processing fresh summer wood. The *variation* in bark content was also reduced in comparison with earlier trials.

Peterson-Pacific DDC 5000 Delimber-Debarker-Chipper

The Peterson-Pacific DDC 5000 is the first integral *delimber-debarker-chipper* unit commercially available. It is mounted on a tri-axle semi-trailer and is manufactured by Peterson-Pacific Corp. of Eugene, Oregon. The DDC 5000 consists of a horizontal double-drum chain flail, a Prentice 180C knuckleboom loader, a Morbark model 23 chipper and a 522-kW Cummins diesel engine (Figure 3). The flail drums are hydrostatically driven at an operating pressure of 27.5 MPA (4000 psi). Each flail drum has 36 lengths of 16-mm flail chain attached, and the flail infeed has a maximum diameter capacity of 56 cm. Feed rate was measured at 30 m/min for an 18-cm diameter tree, down to 22 m/min for a 45-cm diameter tree. Debris removal is by a side-dumping hydraulic ram similar to the Peterson-Pacific model 4800 flail. The current retail price of the unit is $600 000 F.O.B. Ste-Foy, Que.

Figure 3. Peterson-Pacific DDC 5000 delimber-debarker-chipper

Two Peterson-Pacific DDC 5000 machines were studied by FERIC. One was working for Scott Maritimes in New Glasgow, N.S. (Study 1), and the other was operated by Technologic Timber of Armstrong, Ont. (Study 2).

Study 1 (Nova Scotia)

In May 1989, the first Peterson-Pacific DDC 5000 manufactured was introduced to the mixed-wood logging operations of Scott Maritimes Ltd. at New Glasgow, Nova Scotia. Prior to the purchase of the DDC 5000, the company had investigated the concept of flail delimber-debarkers with trials of the Peterson-Pacific model 4800 [1].

Production data on the DDC 5000 was collected by FERIC over five work shifts in August 1989. The machine was working in a hot logging operation processing full-tree yellow birch and sugar maple. Tree size averaged 0.14 m^3 per tree. In addition, a fibre balance analysis was conducted where all input material to the flail and all output material including chips, flail residues and chipper residues were weighed.

The company collected additional data over 15 work shifts between October and December 1989 and provided this information to FERIC. During this second study, tree size averaged 0.16 m^3/tree in hardwood and 0.10 m^3/tree in softwood. No mechanical availability figures were available from this operation.

Productivity

The results of the production study are given in Table 3. During the summer sampling (August), productivity averaged 27.8 mgt/PMH (18.1 odt/PMH), with a maximum of 31.3 mgt/PMH (20.4 odt/PMH). The flail processing rate ranged from 125 to 220 trees/PMH and the average number of trees per loader cycle was 2.5 (range 1-10).

Table 3. Summary of DDC 5000 productivity

	August 1989	October - November 1989	
Length of study (shifts)	5[1]	8[1]	7[2]
Average tree volume (m^3)	0.14	0.16	0.10
Green tonnes per PMH	27.8	37.2	31.0
Oven-dry tonnes per PMH	18.1	24.2	18.6
Trees per PMH	183	222	280
Machine utilization (%)	67.6	|---- 78.7 ----|	

1 - full-tree hardwood
2 - full-tree softwood

Later results from the company study during eight work shifts in October to November 1989, when the machine was again processing hardwoods, showed that average productivity had increased to 37.2 mgt/PMH (24.2 odt/PMH). Data collected by the company during seven work shifts while the DDC 5000 was processing full-tree softwood, showed a productivity averaging 31.0 mgt/PMH (18.6 odt/PMH) or 280 trees/PMH.

Between August and December 1989, flail utilization increased from 67.6% to 78.7% (Table 4). This was primarily caused by a reduction in operational delays relating to machine travel and setting up time.

Table 4. Distribution of DDC 5000 work activity (n = 4069 observations)

Activity	August 1989 (805 observations) % of total time	Oct. - Nov. 1989 (3264 observations) % of total time
Productive time	67.6	78.7
Wait for skidder	-	1.7
Wait for on-loader	12.6	5.6
Position/change vans	3.6	3.4
Mechanical delays	0.3	5.4
Operational delays	15.9	5.2
Total time	100.0	100.0

Fibre Balance and Wood Loss

To assess the fibre recovery efficiency of this type of in-woods chipping operation, a fibre balance study of the DDC 5000 was conducted by FERIC during the August trial in cooperation with Scott Maritimes Ltd. A sample of 118 sugar maple and yellow birch full trees were measured and weighed. Tree size averaged 24.9 cm in butt diameter or 0.18 m^3/tree. The sample trees were then processed and debris from the flail and from the debris separator of the chipper was collected and weighed.

The recovery of "clean" chips averaged 81.3% of total input weight (Table 5). Given the average machine productivity of 27.8 mgt/PMH, the rate of residue production averaged 6.4 mgt/PMH. Wood loss during flail debarking was determined by examining a small sample of the flail residues. This residue had been collected from the front of the flail (branches, bark and foliage) and also from the side of the flail (mainly branches). For the purposes of the study, wood loss was defined as the weight of *stem* wood lost during delimbing and debarking as a proportion of total chips produced (green basis). Wood losses during chipping were not considered during this study. Stem wood represented 6.1% of the flail residues, resulting in a wood fibre loss of 1.3% while processing hardwood of 25 cm diameter on average during the summer.

Table 5. Fibre balance results of DDC 5000 operation (Sugar maple/ yellow birch; August 1989)

	Green weight (kg)	(% of input)
Total tree input (n = 118)	27 345	100.0
Output of clean chips	22 220	81.3
Total flail residues	4 628	16.9
- Bark, branches and foliage	4 345	-
- Stem wood fibre	282	-
Chipper residues	497	1.8

Chip samples from the trial load yielded a bark content of 2.4%, with 87.2% acceptable chips (Table 6). Since the company allows 5% tolerance for oversized material, undersized material, bark and rot, 92.2% of the chips were acceptable to *them*.

Table 6. Summary of chip quality; DDC 5000 (Hardwood; August 1989)

	Trial load (August 1989)
Oversize; >38 mm (%)	7.0
Fines; <3 mm (%)	3.4
Bark and rot (%)	2.4
Accepts (%)	87.2

Study 2 (Ontario)

The second Peterson-Pacific DDC 5000 unit manufactured was purchased in August, 1989 by Technologic Timber Ltd. of Armstrong, Ontario. This machine supplied softwood chips to the Canadian Pacific Forest Products Ltd. mill at Thunder Bay, Ontario. This full-tree hot logging operation was studied during two work shifts in December 1989. The DDC 5000 was working at roadside processing frozen mixed jack pine and spruce. Average tree diameter was 16.7 cm and tree size averaged 0.18 m^3 per tree. The loading of eight chip vans was measured and 200 activity sampling observations were made.

Performance

During the FERIC study, productivity averaged 29.5 mgt/PMH or 18.6 odt/PMH (Table 7). Total processing time averaged 60.2 minutes per van load, including clearing slash and other operational delays. The number of trees per loader cycle ranged from 1 to 10 and averaged 2.8 trees/cycle.

Table 7. Summary of DDC 5000 productivity (Softwood; December 1989)

Length of study (shifts)	2
Average tree volume (m^3)	0.18
Green tonnes per PMH	29.5
Oven-dry tonnes per PMH	18.6
Trees per PMH	164
Machine utilization (%)	51

During the FERIC study, the flail-chipper was productive only 51.0% of total time (Table 8). Waiting for chip vans and waiting for wood constituted the greatest delays to the flail-chipper operation. Only one grapple skidder was forwarding wood to the flail and simply could not keep up as skid distance increased. The operational logistics of chip van scheduling was considered by the company to be the major area for improvement in this operation.

Table 8. Distribution of DDC 5000 work activity (n = 200 observations)

Activity	% of total time
Productive time	51.0
Wait for skidder	12.0
Wait for on-loader	5.5
Wait for vans	14.5
Position/change vans	2.5
Mechanical delays	5.5
Personal delays	9.0
Total	100.0

Table 9 presents the average bark content and chip quality data from the loads sampled during the FERIC study. Because of the very cold ambient temperature during the study, the proportion of fines was high because of chip breakage during the processing and loading phases. Bark content averaged 0.5% in these frozen wood conditions. The extreme cold may also have had a positive effect on the bark content since the bark seemed to shatter after contact with the flails. The average bark content from 467 softwood loads sampled by the company during the summer was 1.4%.

Table 9. Summary of chip quality; DDC 5000 (Softwood; December 1989)

Oversize; >32 mm (%)	3.2
Fines; <6 mm (%)	8.1
Bark content (%)	0.5
Slivers & knots (%)	0.9
Rotten wood (%)	0.3
Accepts (%)	87.0

Discussion

1. Overall Performance

During the trials, both the Forest Pro and the DDC 5000 demonstrated their potential to produce debarked wood suitable for chip production at a quality level acceptable to the mills supplied. Results showed that, although the operations studied were in an early stage of development, an average productivity of 30 green tonnes of chips per productive machine hour is realistic and achievable. It is likely that productivity will increase as operational logistics are improved and operators become more experienced. There was only a small difference in flail productivity between hardwoods and softwoods during the study of the DDC 5000 in Nova Scotia.

One major advantage of flail delimber-debarkers is that they can process multiple trees, and are thus less affected by tree size. The flails studied processed between 2.5 and 2.8 trees per loader cycle, with a maximum of 10 trees/cycle. The processing rate of the flails studied ranged from 160 to 280 trees per PMH. In general, the larger the tree, the slower the feed rate. Productivity in green tonnes per PMH however, increased as tree size increased.

Bark content varied from 0.5 to 2.4% during the trials and there was evidence that this factor is affected by tree species and temperature. In general, the studies indicated that a bark content of less than 1% could be achieved, but the level obtained will represent a trade-off with productivity. This topic deserves further investigation under a variety of operating conditions.

2. Fibre Loss

The measured recovery efficiency of 81.3% during the DDC 5000 fibre balance study at Scott Maritimes is comparable to the results of a study of a Peterson-Pacific model 4800 flail in 21-year-old slash pine in the southern U.S.A. [3]. This report also indicated that in-woods flail/chipping recovered 2.9% more tree biomass as clean chips than tree-length harvesting using a drum debarker at the mill. A study of the DDC 5000 by CPFP Ltd. in Ontario, found a net fibre recovery gain of 4.4% in terms of required m^3/odt of chips produced in comparison with conventional roundwood operations.

These studies indicate that the fibre recovery efficiency of flail/chipping systems may be greater than that of conventional roundwood operations. This increase in recovery efficiency may arise from improved utilization of the input furnish and a better ability to accept undersized and deformed stems. The degree of wood loss calculated from the study of the DDC 5000 in Nova Scotia was negligible compared to the potential increased fibre recovery efficiency of this technology. Further trials examining the wood loss from flail delimber-debarkers should be undertaken to validate these preliminary results.

3. System Interactions

As far as operational logistics are concerned, the use of chain flail delimber-debarkers has not evolved to its full potential in eastern Canadian conditions. During the FERIC studies, flail utilization ranged from 51.0 to 78.7%. The machines studied were operating in hot logging systems, resulting in "waiting for wood" delays ranging between 1.7 and 12.0%. The ability to operate in a cold deck operation is the key to integrating flail technology easily into the Canadian logging industry. In eastern Canada, hot logging is not a common approach because of the requirements for large prepared landings on firm ground, long skidding distances, the close interdependence of the different phases and debris disposal problems. To date, the Peterson-Pacific DDC 5000 is the only commercial model of flail delimber-debarker that has been worked along roadside piles of trees. Even with this machine, problems with mobility exist in that the unit is trailer-mounted and must be operated on the road. The narrowness of most forest roads creates positioning problems during van changeovers.

Centralized processing does however have advantages also. While there is a need for large, higher-quality landings capable of supporting heavy traffic, the *total* landing area required is reduced. Moreover, the delimbing/debarking residues generated are concentrated in one location which can facilitate their collection and subsequent disposal/utilization. Hot logging systems also ensure fresher fibre to the mill because of reduced in-woods inventory. With proper planning of raw material delivery to the landing and chip van avail-ability, processing productivity can be maintained at a very high level.

One major logistical problem of current flail/chipping operations is chip van scheduling. The advantages of high flail processing productivity are offset by long waiting times for chip vans. Central chip van scheduling control and radio communication between trucks and the flail operation would reduce delays between van arrivals and also provide better coordination between productive time and scheduled maintenance.

Several other operational questions must be answered before chain flail processing reaches its full potential in eastern Canada. These will be the object of future research activities by FERIC and include:

- coordination of the felling, skidding and processing phases;
- appropriate landing lay-out;
- optimizing full-tree delivery to the flail and flail in-feed systems;
- improved chip van scheduling and landing maneuvers;
- alternatives for residue evacuation, collection and disposal.

Conclusion

Flail processing is a re-emerging technology that has interesting potential in eastern Canada. The advantages of in-woods flail/chipping systems are numerous if a number of key factors can be controlled. Of primary importance, the product must meet mill specifications with respect to chip quality. FERIC studies suggest that bark contents of less than 1% are achievable while maintaining satisfactory productivity and acceptable fibre loss.

Flail delimbing and debarking coupled with in-woods chipping may offer the possibility for forest managers to significantly increase the yield per unit area of their forest resource. Other potential advantages of flail/chipping systems include improving wood flow control through hauling chips directly to the mill, and through providing a means to supplement existing woodroom capacity. By processing full trees to clean chips in one operation, in-woods flail/chipping systems also offer the potential to substantially reduce harvesting costs.

Several problems associated with in-woods chipping using chain flail delimbing-debarking technology should be addressed in future research efforts. These include the operational logistics of these systems, chain wear concerns, residue generation and disposal, chip van scheduling and positioning, finding the optimum productivity/fibre loss/bark content operating combination, and chip quality control concerns.

A FERIC project started in 1990 will examine the overall economics of flail delimber-debarkers, satellite woodyards and in-woods flail/chipping systems. The quality and cost of chips produced from various debarking systems will be evaluated, and the implications at the mill for each system will be assessed.

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