HARVESTING & PROCESSING

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SURVEY OF MECHANIZED PROCESSING EQUIPMENT
Evaluation of the Caterpillar DL221 Processor

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Summary and Conclusions

The objective of this study was to measure the productivity and cost of a Caterpillar DL221 processor working in coastal old-growth timber. The study was done at MacMillan Bloedel Limited's Northwest Bay Division on Vancouver Island, B.C.

FERIC monitored the machine's performance in two areas for five days in January 1987. The machine processed 26 trees per productive machine hour (PMH), for a volume produced per scheduled machine hour (SMH) of 20.4 m³. Costs were $5.44/m³ or $8.06/tree.

Machine utilization was low during the study period (52.6%) but our observations indicate a 73% utilization rate is achievable. This would result in a production rate of 226.4 m³ per 8-hour shift for a cost of $3.93/m³. To achieve this utilization level, modifications must be made to the processor.

Well prepared windrows of trees are critical for efficient, cost-effective mechanical processing. Trees should be presented with butts facing the road and piled parallel to each other. The absence of a dirt bank caused by road construction also facilitates processing efficiency. This was highlighted in the study when a well prepared windrow of trees and the absence of a dirt bank resulted in a 90% increase in the number of trees processed per PMH.

Introduction

Many coastal operations have smallwood old-growth stands in which 90% or more of the stems have a butt diameter of less than 60 cm. These stands could be mechanically processed with a suitable machine.

Keywords: Delimbing, Slashing, Processors, Machine Evaluation, Productivity, Costs, Downtime, Caterpillar DL221 Processor

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The concept of the Caterpillar DL221 processor originated with Tanguay Industries Ltd., St-Prime, Quebec, with the first prototype produced in 1982. To assess the Caterpillar DL221 processor's suitability for processing West Coast timber, Finning Tractor & Equipment Co. Ltd. of Vancouver, B.C. conducted initial field trials near Vancouver in 1986. After some modifications to the processing head, the machine was transported to Vancouver Island for further field trials. In January 1987, FERIC was asked to monitor and report on a demonstration trial being conducted near Buckley Bay, B.C.

Site and System Description

The study site was located on the east coast of Vancouver Island, 16 km west of Buckley Bay, B.C. Species composition, by volume, was 50% balsam fir, 39% western hemlock, and 11% western red cedar. The stand had 454 stems per hectare, with a net volume per hectare of 690 m^3.

A Madill 084 grapple yarder was used to yard timber which had been either handfelled or mechanically felled. Trees were yarded to the roadside and windrowed along the road (Figure A). After processing, logs were loaded by a Caterpillar 225 log loader, and highway hauled to the dryland sortyard near Parksville, B.C.

FIGURE A. Madill 084 Grapple Yarder and Windrowed Trees (Area B).

The study site included two different operating areas:

Area A
- wood was feller-bunched and grapple yarded to windrow
- level ground (±5%)
- most trees in the windrow had butts facing the road
- absence of dirt bank at roadside

Area B
- handfelled and grapple yarded to windrow
- windrow on downhill side of road
- windrow contained many bucked logs (some cedar logs up to 150 cm in diameter)
- windrow also contained many trees with tops facing the road
- dirt bank, up to 3 m in height (Figure A), on downhill side of road (caused by road construction)
- slope on lower side of road varied from 30 to 50%

The Caterpillar DL221 processor has a Tanguay EC200 processor upper section which is mounted on a Tanguay AC200 feller-buncher undercarriage. Table 1 gives the processor specifications.

TABLE 1. Caterpillar DL221 Processor Specifications.

Upper Section	
Model	Tanguay EC200 Processor
Delimbing	Boom Extension = 7.3 m Backward Stroke = 2.5 m
Delimbing Force	6350 kg max from the holding grapple
Tree-Holding Grapple Opening	66 cm
Delimbing Head Capacity	56 cm
Saw Capacity	66-cm Bucking Bar 53-cm Topping Bar
Lower Section	
Model	Tanguay AC200 Feller-Buncher
Engine	Caterpillar 3208 (122 kW)
Fuel Reservoir	750 L
Tilt Capacity	Four-way tilt with capacity to adjust turntable up to 13 degrees from track
Rotation	Continuous Rotation
Weight	Approximately 26 000 kg

A knuckle-boom loader stroke, plus a backward stroke by a hydraulic cylinder, is used to process trees. The full extension of the boom, in addition to the backward stroke of the tree-holding grapple, results in a total extended length of 12.2 m (Figure B). The processing sequence (Folkema 1982) includes:

1) Load Tree - (Figure C) the boom grapple is extended to a tree and the tree is drawn to the tree-holding grapple. The tree-holding grapple then closes and secures the tree.

2) Delimb/Measure/Buck - (Figure D) the knuckle-boom is extended, thereby delimbing the tree with the delimbing knives and grapples. For longer trees, the knuckle-boom and the backward stroke cylinder are extended simultaneously. At the maximum extension of the boom, the roles of the two sets of grapples are reversed and the boom is retracted. This reciprocating action is repeated until the desired log length is reached. The tree is then bucked or topped by the topping saw.

3) Reverse Log to Unload - The log is retracted and piled.

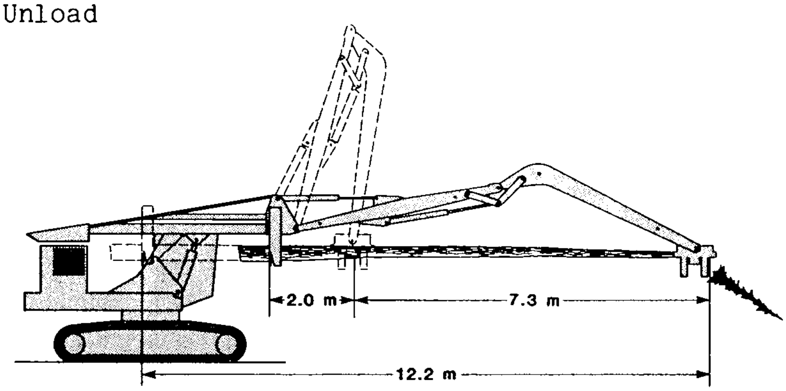

FIGURE B. Machine Dimensions.

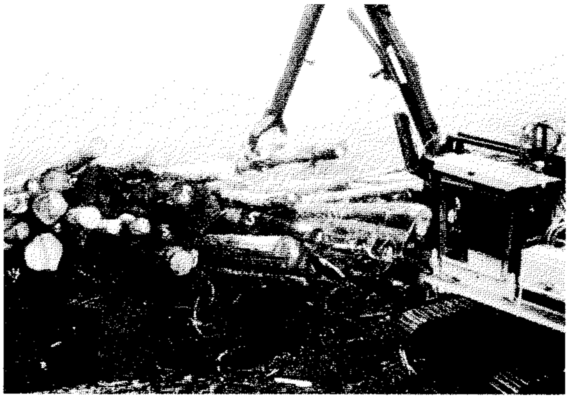

FIGURE C. Load Sequence.

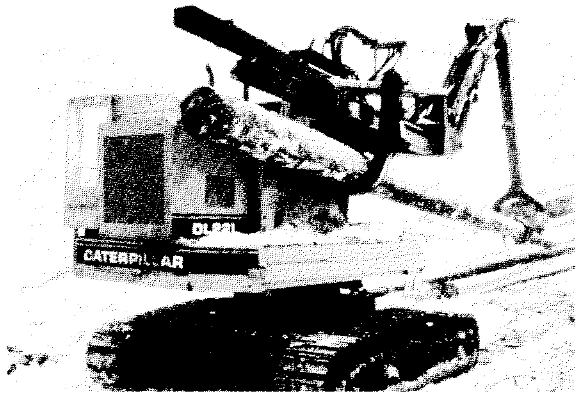

FIGURE D. Delimb/Measure/Buck Sequence.

Results and Discussion

Table 2 shows the observed time-distribution summary. "Process" time includes the functions of loading the tree, delimbing, measuring, bucking, unloading the tree, and the required swinging time to do these functions. Processing time averaged 1.2 min/tree in Area A and 1.6 min/tree in Area B. FERIC observed the delimbing efficiency and quality to be good on limbs up to 8 cm in diameter.

TABLE 2. Observed Time-Distribution Summary.

Phase	Area A		Area B		Combined	
	Hours	%	Hours	%	Hours	%
Productive Time						
Move	0.1	1.7	1.0	3.5	1.1	3.2
Move Logs	0.4	6.6	3.0	10.5	3.4	9.8
Process	3.2	53.3	8.3	29.0	11.5	33.2
Swing Trees	0.1	1.7	2.1	7.4	2.2	6.4
Subtotal	3.8	63.3	14.4	50.4	18.2	52.6
Non-Productive Time						
Mechanical	1.6	26.7	8.7	30.4	10.3	29.8
Other	0.6	10.0	5.5	19.2	6.1	17.6
Subtotal	2.2	36.7	14.2	49.6	16.4	47.4
Total	6.0	100.0	28.6	100.0	34.6	100.0
Number of Trees Processed	159		317		476	
Number of Logs Processed	260		497		757	
Number of Logs Moved	69		371		440	
Number of Trees Swung	9		123		132	
Number of Long Butt Cuts	52		43		95	
Process Time per Tree, min	1.2		1.6		1.4	
Process Time per Log, min	0.7		1.0		0.9	
Average Gross Volume per Tree Processed, m^3	1.32		1.56		1.48	
No. of Trees Processed per PMH	41.8		22.0		26.2	
No. of Trees Processed per SMH	26.5		11.1		13.8	
No. of Logs Processed per PMH	68.4		34.5		41.6	
No. of Logs Processed per SMH	43.3		17.4		21.9	
Volume Processed per PMH, m^3	55.2		34.3		38.8	
Volume Processed per SMH, m^3	35.0		17.3		20.4	
Production per 8-hour Shift						
Number Trees	212.0		88.8		110.4	
Volume, m^3	279.8		138.5		163.4	
Total Equipment Cost per 8-hour Shift	$889.52		$889.52		$889.52	
Cost per Tree	$4.20		$10.02		$8.06	
Cost per m^3	$3.18		$6.42		$5.44	

"Move Logs" is the time spent moving logs which were already processed by the handfaller. Ten percent of the combined total time was spent in this function. The handfelled windrow contained more bucked logs than the mechanically felled area.

The "Swing Trees" category represents the time spent swinging trees whose tops faced the road (Figure E). These trees were swung and placed in piles (parallel to the road) for subsequent processing. The windrow in the handfelled area contained significantly more trees that required swinging. As a result, 15% of productive time was spent swinging trees in the handfelled area (Area B) versus 3% in the feller-bunched area (Area A).

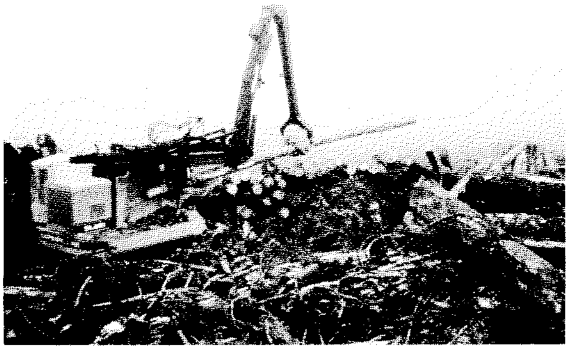

FIGURE E. Processor Swinging Tree.

The limiting factor on the processor's ability to lift and swing trees was the holding power of the delimbing grapple. A tree that approached the maximum lifting capacity was a Douglas-fir, (62-cm diameter, 26-cm top diameter, 28.8-m long, and 3270 kg). The processor was only able to lift this tree slowly and swing it approximately 10 m before it dropped out of the grapples.

"Move" time is the time spent travelling along the windrow while processing. The dirt bank on the lower side of the road in Area B was up to 3 m in height in places. This dirt bank interfered with the operator's ability to see and with the machine's ability to align itself with trees. Also, it caused the windrowed trees to lie at a steeper angle than was necessary and they tended to slide downhill when disturbed. In Area A, the trees were better aligned and most of the butts faced the road, so less moving was required by the processor. FERIC feels that a rotating-head feature would significantly reduce the amount of machine move time involved.

The mean values and the standard deviation for "Process" time were computed by tree diameter class to show the range of values observed in the study (Table 3). Times ranged from a low of 0.35 min/tree to a high of 4.72 min/tree. Mean times progressively increased with increasing tree diameter size. The mean processing times in Area B were consistently higher than those in Area A. This was caused by the steeper angle of the windrow and the number of tangled trees. Volume produced per minute is also shown in this table. There is a progressive increase in production as the trees get larger.

TABLE 3. Productivity by Butt Diameter Class.

Butt Diameter Class Midpoint (cm)	Gross Merch Volume (m^3/tree)	Processing Time/Tree							
		Number of Observations		Mean		Standard Deviation		Volume/Min	
		Area A	Area B	Area A (min)	Area B (min)	Area A (min)	Area B (min)	Area A (m^3)	Area B (m^3)
10	0.06	3	6	0.51	0.79	0.18	0.30	0.12	0.08
20	0.23	30	26	0.69	0.84	0.18	0.24	0.33	0.27
30	0.77	37	44	1.02	1.32	0.21	0.50	0.75	0.58
40	1.62	53	79	1.35	1.97	0.58	0.71	1.20	0.82
50	2.84	23	45	1.68	2.45	0.73	0.87	1.69	1.16
60	4.22	2	6	2.65	3.09	0.18	1.11	1.59	1.37

Non-productive time includes all delays no matter what their duration. A detailed summary of non-productive time is shown in Table 4. The majority of mechanical delays (66%) were in the saw category and included chains breaking, chains jumping off, and bent bars. The other major delay (19%) was caused by the boom-level-monitoring cable breaking.

TABLE 4. Summary of Non-Productive Time.

Phase	Area A		Area B	
	Number of Occurrences	Total Minutes	Number of Occurrences	Total Minutes
Mechanical				
Boom-Level-Monitoring Cable Repair			3	120
Clean Electronic Eyes	6	4	16	17
Engine Cover - Tie Down			1	13
Head Cover - Tie Down	1	15		
Hydraulic Fittings - Tighten			2	14
Saws - Bar & Chain Service or Replace	7	68	16	141
- Repair Bent Motor Mount			3	200
Service	2	9	3	19
Subtotal	16	96	44	524
Other				
Clean Debris off Road			18	8
Coffee Break			2	10
Fuel	1	20	1	8
Measurement Accuracy Check			5	16
Other			5	15
Phone	1	14	3	28
Talk to Foreman			2	7
Unknown	1	1	5	6
Visitors			7	148
Wait for Parts			1	82
Subtotal	3	35	49	328
Total	19	131	93	852

FERIC feels that improvements can be made which will increase machine utilization. Suggestions made to Finning Tractor & Equipment Co. Ltd. include:

1)	Boom-Level-Monitoring Cable	-	increase cable size or monitor a different way (rods, electrical, electronic eye, other).
2)	Engine Cover	-	change or modify the tie-down clamps to ensure they will not come undone while machine is operating.
3)	Saw Bar and Chains	-	change to a bar and chain more suited to high-speed service.
		-	modify head to allow bar to retract further into sheath and/or increase amount of guarding.

If the visitors time (148 min), the boom-level-monitoring-cable repair time (120 min), the engine cover time (13 min), and only one-third of the saw-repair time (136 min) is converted to productive time, the machine utilization increases to 73 percent. FERIC believes that this machine utilization level can be achieved if modifications are made to the processor. Finning Tractor & Equipment Co. Ltd. have advised FERIC that they are undertaking a program to improve this machine.

The labour rate used in the cost analysis is the current B.C. IWA rate plus 35% burden (Appendix). Machinery costs are estimated by FERIC and are based on information from equipment and supplies distributors and use a standard owning, repairing, and operating formula format. Costs such as supervision, overhead, and crew and equipment transportation are not included. Also, interest or opportunity costs are excluded from the machinery costs reported in the text, but are listed in the Appendix. Tree volumes were based on FERIC measurements in the stand.

The Area A operation produced costs of \$3.18/m^3 or \$4.20/tree, with a volume of 280 m^3 per 8-hour shift. With a utilization level of 73%, costs in Area A would be \$2.73/m^3. Area B produced costs of \$6.42/m^3 or \$10.02/tree, and a volume of 139 m^3 per 8-hour shift. Given a utilization level of 73%, the Area B cost would be \$4.45/m^3.

REFERENCES

Folkema, M.P. 1982. Evaluation of the Tanguay EC-200 delimber. Forest Engineering Research Institute of Canada. Technical Note. No. TN-63.

APPENDIX

Machine Cost Analysis

OWNERSHIP COSTS

Purchase Price (P)	$412 000
Salvage Value (S), (20% of P)	$ 82 400
Expected Life (yr)	6
Expected Life (h)	9 600
Interest Rate (I) %	12
Insurance Rate (Ins) %	3
Average Investment (AVI) = (P+S)/2	$247 200
Loss in Resale Value ($/h) = (P-S)/h	$34.33/h
Interest ($/h) = (I*AVI)/(h/yr)	$18.54/h
Insurance ($/h) = (Ins*AVI)/h/yr)	$ 4.64/h

OPERATING AND REPAIR COSTS

Fuel Consumption (L/h)	25
Fuel Cost ($/L)	$ 0.40
Track & Undercarriage Life (h)	5 000
Track & Undercarriage Replacement Costs (T)	$ 12 000
Annual Repair and Maintenance Cost (R)	$ 55 000
Wages ($/h)	$ 17.73
Wage Benefit Loading (%)	35
Fuel Cost = (L/h)*($/L)	$10.00/h
Lube & Oil Cost = 15% * Fuel Cost	$ 1.50/h
Track & Undercarriage Cost = (T/h)	$ 2.40/h
Annual Repair and Maintenance Cost = R/(h/yr)	$34.38/h
Labour Cost = ($/h)*[1+(%/100)]	$23.94/h
Operating and Repair Costs ($/h)	$72.22/h

TOTAL COSTS

Operating and Repair Cost ($/h)	$ 72.22/h
Loss in Resale Value ($/h)	$ 34.33/h
Insurance ($/h)	$ 4.64/h
Total Cost ($/h)	$111.19/h
Interest ($/h)	$ 18.54/h
Grand Total	$129.73/h