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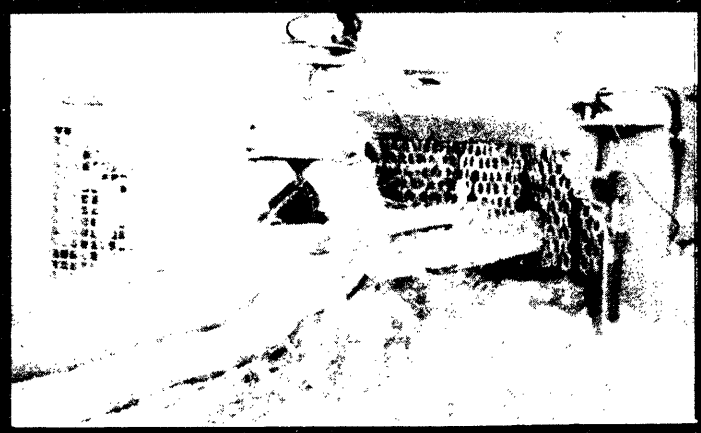

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Whole-tree chipping in the woods is a cost-effective method of producing chips for the forest products industry. A major disadvantage of this system, however, is the poor chip quality that results when leaves, bark, branchwood, and grit are included with the chipped stem. The chain flail delimber/debarker is a recently reintroduced technology being used to improve the quality of whole-tree chips. This machine consists of two or more parallel shafts with many chains mounted on the periphery of integral drums. The shafts are run at high speed as the whole tree is passed through the field of rotating chains. Bark and limbs are removed by the resulting mechanical interaction. This provides relatively clean stems to the chipper, resulting in less bark and grit in the furnish. An assessment of the performance and cost of flail debarking was needed to determine the viability of using this concept to improve the quality of chips produced in the woods.

Although the concept of flail debarking was introduced many years ago in the American forest industry, it did not receive serious interest until very recently (Stephenson 1989). The Peterson Pacific[1] delimber/debarker was conceived and built about 1985. Several years of redesign and development have resulted in the current Model 4800 and the DDC-5000 (which incorporates the delimbing/debarking function with chipping into one machine). We chose to evaluate a Model 4800 because of its proximity and owner cooperation.

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Several case studies of the Model 4800 have been performed under both northern and southern conditions (Bialozynski 1989, Carte *et al.* 1989, Creelman 1989, Grace *et al.* 1988, Sauder and Sinclair 1989, Stokes *et al.* 1989). These studies show that bark content of the chips can be held to 4 percent or less, depending on the species, feed rate, tree size, time of year, and condition of the flail chains. Production rates varied with species, tree size, and target bark percentages, but typically averaged between 20 and 40 green tons per scheduled hour (SH). The flail was evaluated while processing northern hardwoods in the Northeast under conditions similar to the Lake States (Bialozynski 1989). Productivity of the unit averaged 32.6 tons per hour, and bark content was held to about 3.1 percent.

Chain wear and the associated costs are of concern to contractors with chain flail equipment. When processing pines in the South, chains had to be replaced every 30 productive hours, resulting in a chain cost of about $0.50 per green ton (Stokes *et al.* 1989). When processing frozen wood in the North, chains had to be replaced more frequently, resulting in a cost between $1.50 and $2.00 per green ton (Sauder and Sinclair 1989). Feed rate differences between the flail and the chipper were cited as a problem in a few studies because they affected limb/bark removal and chip quality (Creelman 1989, Sauder and Sinclair 1989).

[1]*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.*

A study was undertaken to evaluate the performance and cost of a Peterson Pacific 4800 portable chain flail delimber/debarker operating in conjunction with a conventional in-woods chipping system (fig. 1). The information gathered in this study will be used to compare the performance of a portable chain flail with that of a mobile chain flail (fig. 2) for in-woods chipping.

RESEARCH METHODS

The Peterson Pacific chain flail delimber/debarker we evaluated was operating in the western Upper Peninsula of Michigan for an 8-month trial period from September 1989 to April 1990. Shift level information was collected by the operator of the flail during this period to characterize events that were less cyclic in

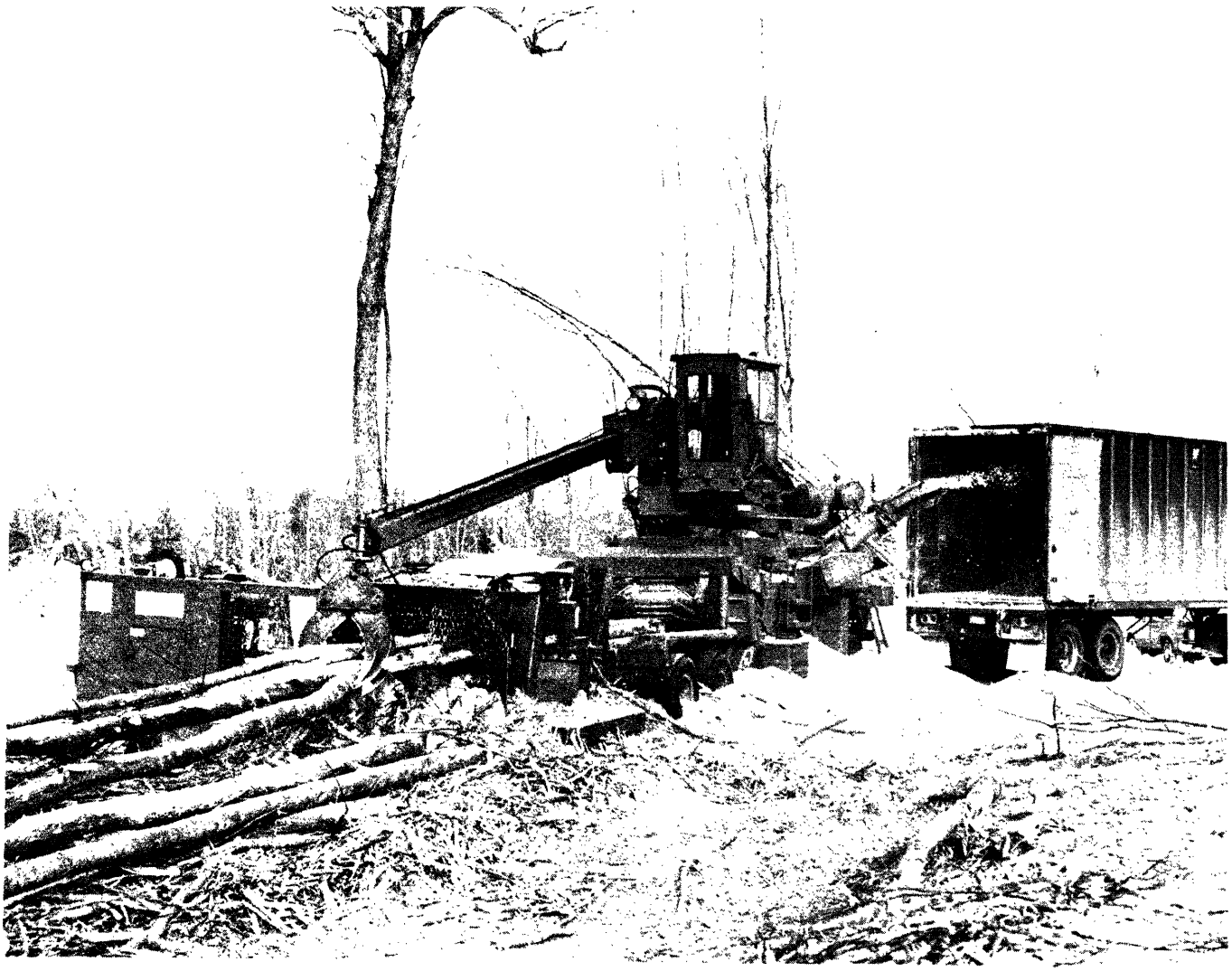

Figure 1.—*A Peterson Pacific 4800 portable chain flail delimber/debarker processing northern hardwoods in tandem with an in-woods chipper.*

nature, such as fuel consumption, chain replacement, equipment breakdowns, and other major delays in the system. This information was used to determine the long-term mechanical availability, utilization, and operating cost of the flail.

Detailed, continuous time study of the flail was conducted for 29 loads during 8 working days from February to April 1990. The number of stems to fill a van was tallied by species (hardwood and aspen). This information was collected at two different sites containing primarily northern hardwoods from 4 to 12 inches diameter at breast height and averaging about 8 cubic feet per tree. Temperatures ranged from 10 to 50° F during the timing periods. Climatic moisture conditions ranged from wet to dry.

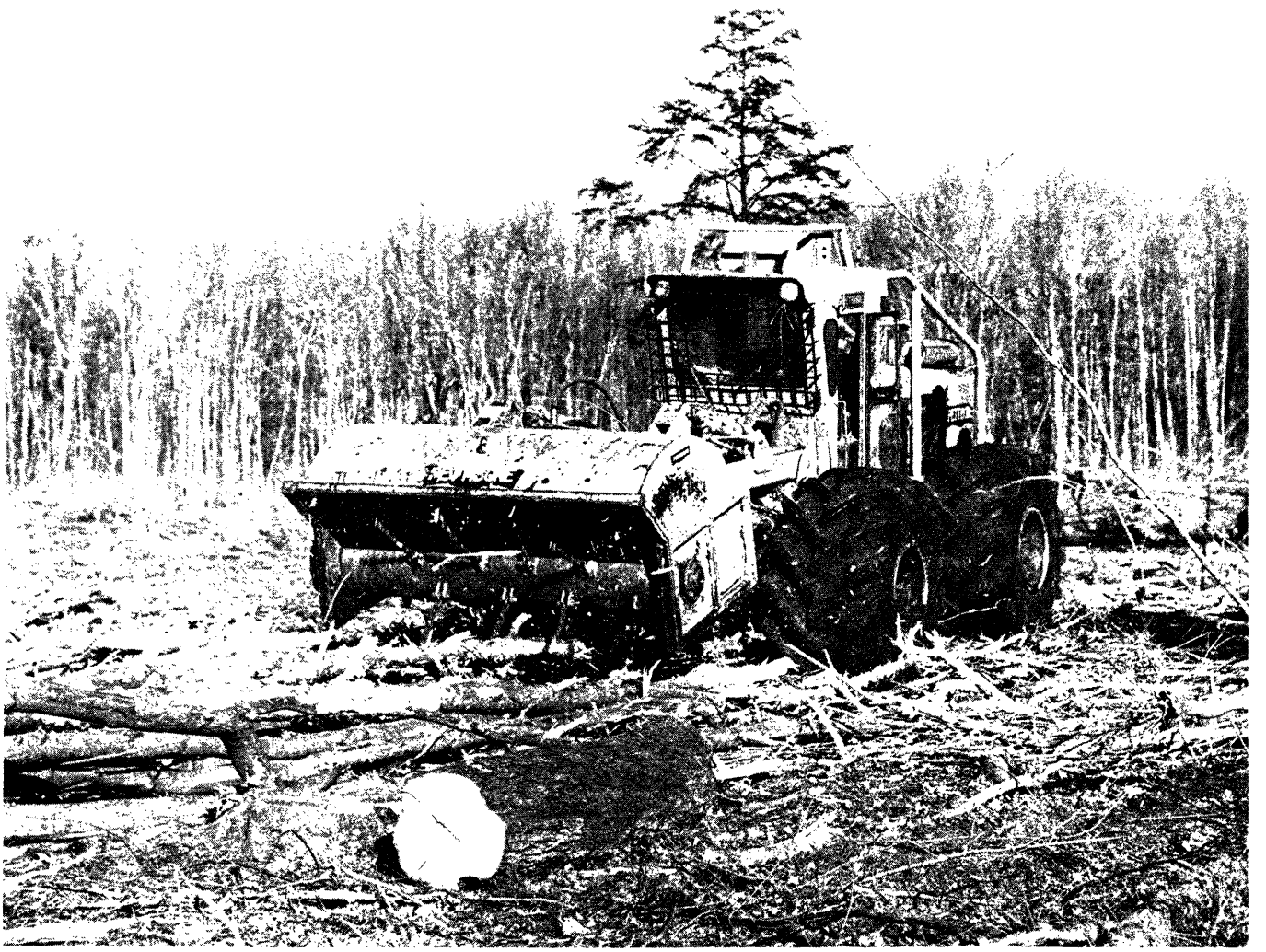

Figure 2.—*A mobile chain flail often used in conventional chipping systems.*

Chip quality samples were taken by Stone Container Corporation in Ontonagon, Michigan, over the 8-month trial period to determine average chip quality for the portable chain flail system. This was contrasted against chip quality samples from a conventional chipping system that used a mobile chain flail operating at the same site. Each sample was fractionated into size classes using a Weyerhauser chip classifier. Bark was then removed from chips of each size class and tallied as a percentage of the total weight.

FLAIL PERFORMANCE

Flail performance can be characterized by assessing the productive potential of the unit, the delimbing/debarking quality achieved during processing, and the costs associated with operating the unit.

Flail Productivity

The flail produced an average of 33.8 tons per SH, based on an average time of 46.1 minutes to flail an average 26 tons of material. The time elements observed during continuous time study of the operation are presented in table 1. The observed utilization of the flail was 62 percent, and the mechanical availability was 90 percent. These results agree with the productivity of 30 to 60 tons per productive hour (18 to 36 tons per SH) claimed by the manufacturer. This production figure also closely agrees with the 32.6 tons per SH observed under similar conditions in the Northeast (Bialozynski 1989). The machine utilization of 62 percent is similar to that reported by Stokes *et al.* (1989) and Sauder and Sinclair (1989).

In contrast, a conventional whole-tree chipping system with a mobile flail could be expected to produce about 50.8 tons per SH or 50 percent more chips under similar conditions. This is based on observation of the conventional side of the operation studied and previous evaluation of whole-tree chipping systems. Most of this productivity difference can be accounted for by the slower feed rate, decreased infeed capacity, and lower utilization of the portable flail. The lower utilization is due to the extra time needed to clear debris from around the chipper and flail and the extra time spent waiting for wood because the skidder can pile only one load at a time in front of the flail.

Table 1.—*Observed times for flailing small northern hardwoods with a Peterson Pacific 4800 chain flail delimber/debarker*[1]

Element	Elemental time	Portion of total
	Min/van	*Percent*
Productive		
Flail	28.6	62.0
Nonmechanical delay		
Clear debris	2.1	4.6
Wait for wood	2.9	6.3
Trim branches	0.7	1.5
Change van	2.5	5.4
Personal breaks[2]	3.8	8.2
Miscellaneous	0.9	2.0
Total nonmechanical delay	12.9	28.0
Mechanical delay		
Mechanical delays	4.6[3]	10.0
Total time	46.1	100.0
Productivity	26 tons/46.1 min or 33.8 tons/SH[4]	

[1] Based on 29 loads observed during 8 working days over a 2-month period.
[2] Assumed value (not observed).
[3] Based on 8 months of record keeping on the flail unit.
[4] SH = scheduled hours.

Delimbing/Debarking Quality

The ability of the flail to remove bark from the stems depended on tree size, tree species, branchiness, temperature, dryness, feed speed, flail speed, and chain condition. Small trees tended to be debarked better than large trees, presumably because of the thinner bark on small trees. Aspen was more difficult to debark than northern hardwoods. This might be due to the thick, resilient bark on aspen, which comes off easily only in late spring.

The more branches a tree had, the better it was debarked. This is probably due to the slower feed speed resulting from hung branches during infeed. Low temperatures affected debarking quality by adding resiliency to the bark and freezing the bark to the wood. The most difficult debarking seemed to be when the temperature stayed between 20 and 30° F. Prolonged dry periods also seemed to make debarking difficult

by tightening the bark around the stem, increasing bark/wood cohesion.

The speed at which material was fed through the unit affected the amount of interaction between trees and chains. Faster feed speeds resulted in less debarking and vice versa. The rotational speed of the shafts affected the force with which chains hit the trees. Faster shaft speeds will result in better debarking, but may also increase the percentage of fines in the furnish and decrease chain life. The condition of the chains had a marked effect on debarking quality. The unit relies on a full field of chains to accomplish thorough debarking. A few missing links on key chains will visibly reduce the effectiveness of the flail.

The overall effectiveness of the flail in removing bark from the furnish is evident from the average bark contents observed for the conventional system (with a mobile chain flail) operating side-by-side with the portable flail system over the trial period:

Month	Portable flail (Percent)	Mobile flail (Percent)
September	4.6	10.7
October	4.7	9.8
November	4.3	12.5
December	4.4	7.6
January	4.4	7.6
February	4.2	8.8
March	5.1	7.6
April	4.7	9.1
Average	4.6	9.2

The portable flail side consistently produced chips with less bark than the mobile flail side. The overall average was half as much bark. This was achieved with only a 1-percent increase in the amount of fines (less than one-sixteenth of an inch) in the furnish and a beneficial down-shifting of about 7 percent of the material from the oversize category (greater than 1/3-inch thick) to the borderline accepts (1/4-inch screen). No difference in the percentage of acceptable chips (1/2-inch screen) occurred. Managing the flail based on the factors outlined previously might improve this performance. However, there will be a cost associated with further reductions in bark content.

Flail Cost

Standard costing procedures (Miyata 1980) were used to develop costs for typical in-woods chipping systems having either a portable flail or a conventional mobile flail. Table 2 lists the pieces of equipment in each system and their associated hourly costs. Costs are in 1990 dollars and were derived using 1990 equipment prices. Specific details of the costing method are contained in the machine rate sheets in the Appendix. Using this method to estimate cost for the portable flail system resulted in a total cost of $660.08 per SH or $19.53 per ton. The estimated total cost for the mobile flail system on the other hand, was $873.51 per SH or $17.20 per ton. These are delivered costs that do not include stumpage.

The portion of this $19.53 per ton directly attributable to the portable flail is about $1.76 per ton. Flail chains and rods accounted for almost one-third of this cost, adding up to about $0.56 per ton. Chains were turned end-to-end after about 25 loads and had to be replaced about every 50 loads. The remaining $1.20 per ton cost is accounted for by the ownership costs ($0.76 per ton) and other operating expenses ($0.44 per ton).

The portable flail is also indirectly responsible for increasing all other costs in the system due to its effect on productivity. Adding the portable flail to a conventional chipping operation lowers the productivity of the system by about one-third. This results in an estimated overall cost increase of $2.33 per ton for debarked chips.

Pricing structures for chips should account for more than this $2.33 per ton cost differential between the portable and mobile flail systems. For the loggers' profit picture to remain the same after adding the flail, there must be a higher profit margin per ton (difference between price and cost) because fewer tons are produced in a given time period. This relationship is expressed as:

Profit = Productivity (Chip price at mill - Delivered cost)

Table 2.—*Whole-tree chipping costs with a portable or mobile flail*[1]

Equipment	Portable flail system Number	Portable flail system Hourly cost	Mobile flail system Number	Mobile flail system Hourly cost
		1990 $		*1990 $*
Feller buncher	2	138.22	3	207.33
Grapple skidder	2	105.60	3	158.40
Mobile flail	0	—	1	48.45
Stationary flail	1	59.33	0	—
Whole-tree chipper	1	95.00	1	95.00
Truck and van	3	153.60	5	256.00
Service/crew truck	1	23.84	1	23.84
Fuel truck	1	2.52	1	2.52
Pickup truck	1	4.59	1	4.59
Lowboy trailer	1	2.72	1	2.72
Bulldozer	1	48.76	1	48.76
Road grader	1	25.90	1	25.90
Total hourly cost		$660.08		$873.51
Productivity (tons per hour)		33.8		50.8[2]
Cost per ton		$19.53		$17.20

[1] Based on standard costing procedures using 1990 dollars and new equipment prices (Miyata 1980), these are not the actual costs incurred by the system.

[2] Determined from observation of the mobile flail side of the operation studied and previous evaluation of whole-tree chipping systems.

Assuming that the usual price for whole-tree chips is $18.00 per ton and that this price is increased by $2.33 for chips from the portable flail system, a comparison of profit can be made:

	Portable flail	Mobile flail
Price per ton	$20.33	$18.00
Cost per ton	$19.53	$17.20
Hourly production (tons)	33.8	50.8
Hourly profit	$27.04	$40.64

This calculation shows that the logger is making less profit with the portable flail because less wood is being produced. It would be more appropriate to determine chip prices by attempting to equalize the profit per unit time and calculating backwards:

	Portable flail	Mobile flail
Hourly profit	$40.64	$40.64
Cost per ton	$19.53	$17.20
Hourly production	33.8	50.8
Price per ton	$20.73	$18.00

In this example, the chip price per ton that equalized profit would be $2.73 more than the normal price, rather than the $2.33 arrived at by analyzing cost alone. Mills interested in improving chip quality might consider using a sliding price scale based on chip quality measures, such as bark content, size distribution, and grit content. This approach would give the logger the monetary incentive needed to institute the costly system changes required for improving the quality of chips generated in the woods.

CONCLUSIONS

This evaluation of the Peterson Pacific 4800 portable chain flail delimber/debarker has shown that the bark content of whole-tree chips can be significantly reduced during the most difficult debarking months in the North. This reduction comes at a $2.33 per ton cost to the logger, along with a lower chipping productivity. The cost to the mill might be greater if attention is paid to equalizing the logger's profit after adding the flail to the system.

There are two ways to lower the cost of woods debarking with portable chain flails. The first is to improve chain technology. Flail chains alone accounted for more than $0.50 per ton. Further developments in chain technology should reduce this considerably. The second is to separate the delimbing/debarking function from the chipping and balance the productive abilities of the system. This might call for three stationary chain flails processing wood for two chippers. Using this approach, chipper productivity could be maximized, resulting in lower total cost.

Separating the flail and chipper would also better distribute slash across the site rather than around the chipper, and would eliminate the tendency of broken chain links to become feedstock for the chipper, which happens occasionally. Another possible advantage in separating the flail and chipper is an increase in delimbing/debarking quality. In this study, the chipper feed was faster than the flail feed and pulled the material through as soon as it grabbed it. As a result, the residence time of the top half of the tree was less than optimal, visibly reducing the amount of limbs and bark removed. Residence time of the top in the flail should be increased to maximize limb/bark removal.

A disadvantage of separating the two functions would be the addition of grit to the debarked stems as they are dragged from the flail to the chipper. However, this should be of concern only during wet spells on certain sites. Another disadvantage would be the cost of additional flails to balance the system productivity. However, this cost should be easily countered by the increase in system productivity afforded by the flails.

Separating the flail from the chipper would require adding a loader and operator to the system if the Peterson 4800 is used. A more economical solution might be to add a Peterson SLD 6000 flail, which can be fed by the grapple skidder as the load is brought in. The grapple skidders often must wait for the chipper, so this approach should improve wood flow in the system, allowing for maximum system productivity.

SUMMARY

A Peterson Pacific 4800 portable chain flail delimber/debarker was evaluated from September 1989 to April 1990 while processing pole-size northern hardwoods and aspen in northern Michigan. Long-term data describing fuel consumption, chain replacement, equipment breakdowns, and other major delays were obtained from the operator of the flail unit over this period. Detailed cyclic information was collected using continuous time study techniques for 29 loads over 8 working days from February to April 1990. Chip quality samples were collected and analyzed by Stone Container Corporation over the full 8-month trial period.

The flail produced wood at an average rate of 33.8 tons per SH. It took an average of 46.1 minutes to flail an average 26-ton load of chips. In contrast, a conventional chipping operation produces at an average rate of about 50.8 tons per SH. The observed utilization of the flail was 62 percent, and the mechanical availability was about 90 percent. The quality of the delimbing/debarking function was affected by tree size, tree species, branchiness, temperature, dryness, feed speed, flail speed, and condition of the flail chains.

The average bark content of the chips over the 8-month trial period was 9.2 percent for the conventional side of the whole-tree chipping operation. The portable flail side, on the other hand, achieved an average of 4.6 percent bark with much less variability. This was achieved during the worst 8 debarking months of the year. The associated increase in fines was insignificant, especially when the 7 percent downshifting from oversize to borderline accepts is considered.

Using standard costing procedures, 1990 equipment prices, and expected equipment combinations (based on system productivity), we estimate that the total cost to harvest and deliver in-woods debarked chips was $19.53 per ton. The estimated total cost for conventional chips was about $17.20 per ton. This difference can be attributed mainly to the productive advantage of the conventional side. Pricing structures for woods debarked chips should consider the effect of this productivity difference on operator profit.

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APPENDIX

MACHINE RATE CALCULATIONS
(off-road equipment)

month: April
year: 1990

Description

Machine(make,model,type) Tracked limited-area feller-buncher
Accessories or modifications
Engine(Hp,type) 140 Hp diesel

Initial Investment(P) - F.O.B delivered cost = $ 210,000
Economic Life(n) 5 years
Salvage Value(S) 20 % of P = $ 42,000
Scheduled Hours(SH) per Year 2000 hours
Machine Utilization(U) 60 %
Productive Hours(PH) per Year 1200 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 142,800 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 33,600 /yr
Interest 12 %
Insurance 7 %
Taxes 3 %
Overhead 8 %
Total 30 % x AAI $ 142,800 /yr = $ 42,840 /yr

Total Ownership Cost per Year = $ 76,440 /yr

Total Ownership Cost per Scheduled Hour = **$ 38.22 /SH**

Operating Costs

Repair & Service (% of D) 75 % x (D)$ $\frac{33,600 \text{ /yr}}{1200 \text{ PH/yr}}$ = $ 21.00 /PH

Fuel 140 Hp x 0.026 gal/Hp-hr x $ 1.10 /gal = $ 4.00 /PH

Oil & Lubrication 37 % of the fuel cost = $ 1.48 /PH

Tires $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right)\left(\frac{1.15 \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ -NA- /PH

Total Operating Cost per Productive Hour = **$ 26.48 /PH**

Labor Costs

Hourly Wage = $ 10.00 /SH

Wage Taxes 25 % of the hourly wage = $ 2.50 /SH

Fringe Benefits 25 % of the hourly wage = $ 2.50 /SH

Total Labor Cost per Scheduled Hour = **$ 15.00 /SH**

Machine Rate

Total Cost per SH = ownership + operating x U + labor = **$ 69.11 /SH**

MACHINE RATE CALCULATIONS
(off-road equipment)

month: April
year: 1990

Description

Machine(make,model,type) Large grapple skidder
Accessories or modifications
Engine(Hp,type) 140 Hp diesel

Initial Investment(P) - F.O.B delivered cost = $ 125,000
Economic Life(n) 4 years
Salvage Value(S) 20 % of P = $ 25,000
Scheduled Hours(SH) per Year 2000 hours
Machine Utilization(U) 65 %
Productive Hours(PH) per Year 1300 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 87,500 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 25,000 /yr
Interest 12 %
Insurance 7 %
Taxes 3 %
Overhead 8 %
Total 30 % x AAI $ 87,500 /yr = $ 26,250 /yr

Total Ownership Cost per Year = $ 51,250 /yr

Total Ownership Cost per Scheduled Hour = $ 25.63 /SH

Operating Costs

Repair & Service (% of D) 60 % x (D)$ $\frac{25,000 \text{ /yr}}{1300 \text{ PH/yr}}$ = $ 11.54 /PH

Fuel 140 Hp x 0.028 gal/Hp-hr x $ 1.10 /gal = $ 4.31 /PH

Oil & Lubrication 37 % of the fuel cost = $ 1.59 /PH

Tires $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right)\left(\frac{1.15 \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ 1.29 /PH

Total Operating Cost per Productive Hour = $ 18.73 /PH

Labor Costs

Hourly Wage = $ 10.00 /SH

Wage Taxes 25 % of the hourly wage = $ 2.50 /SH

Fringe Benefits 25 % of the hourly wage = $ 2.50 /SH

Total Labor Cost per Scheduled Hour = $ 15.00 /SH

Machine Rate

Total Cost per SH = ownership + operating x U + labor = $ 52.80 /SH

MACHINE RATE CALCULATIONS
(off-road equipment)

month: April
year: 1990

Description

Machine(make,model,type) Mobile chain flail delimber
Accessories or modifications
Engine(Hp,type) 180 Hp diesel

Initial Investment(P) - F.O.B delivered cost = $ 125,000
Economic Life(n) 5 years
Salvage Value(S) 20 % of P = $ 25,000
Scheduled Hours(SH) per Year 2000 hours
Machine Utilization(U) 60 %
Productive Hours(PH) per Year 1200 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 85,000 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 20,000 /yr
Interest 12 %
Insurance 7 %
Taxes 3 %
Overhead 8 %
Total 30 % x AAI $ 85,000 /yr = $ 25,500 /yr

Total Ownership Cost per Year = $ 45,500 /yr

Total Ownership Cost per Scheduled Hour = **$ 22.75 /SH**

Operating Costs

Repair & Service (% of D) 60 % x (D)$ $\frac{20,000 \text{ /yr}}{1200 \text{ PH/yr}}$ = $ 10.00 /PH

Fuel 180 Hp x 0.026 gal/Hp-hr x $ 1.10 /gal = $ 5.15 /PH

Oil & Lubrication 37 % of the fuel cost = $ 1.91 /PH

Tires $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right) \left(\frac{1.15 \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ 0.77 /PH

Total Operating Cost per Productive Hour = **$ 17.83 /PH**

Labor Costs

Hourly Wage = $ 10.00 /SH

Wage Taxes 25 % of the hourly wage = $ 2.50 /SH

Fringe Benefits 25 % of the hourly wage = $ 2.50 /SH

Total Labor Cost per Scheduled Hour = **$ 15.00 /SH**

Machine Rate

Total Cost per SH = ownership + operating x U + labor = **$ 48.45 /SH**

MACHINE RATE CALCULATIONS
(off-road equipment)

month: April
year: 1990

Description

Machine(make,model,type) Portable chain flail delimber/debarker
Accessories or modifications
Engine(Hp,type) 175 Hp diesel

Initial Investment(P) - F.O.B delivered cost = $ 140,000
Economic Life(n) 5 years
Salvage Value(S) 20 % of P = $ 28,000
Scheduled Hours(SH) per Year 2000 hours
Machine Utilization(U) 60 %
Productive Hours(PH) per Year 1200 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 95,200 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 22,400 /yr
Interest 12 %
Insurance 7 %
Taxes 3 %
Overhead 8 %
Total 30 % x AAI $ 95,200 /yr = $ 28,560 /yr

Total Ownership Cost per Year = $ 50,960 /yr

Total Ownership Cost per Scheduled Hour = **$ 25.48 /SH**

Operating Costs

Repair & Service (% of D) 100 % x (D)$ 22,400 /yr / 1200 PH/yr = $ 18.67 /PH
Fuel 175 Hp x 0.023 gal/Hp-hr x $ 1.10 /gal = $ 4.43 /PH

Oil & Lubrication 37 % of the fuel cost = $ 1.64 /PH

Chains and rods $700/24 + $500/200 = $ 31.67 /PH

Total Operating Cost per Productive Hour = **$ 56.41 /PH**

Labor Costs

Hourly Wage = $ /SH

Wage Taxes % of the hourly wage = $ /SH

Fringe Benefits % of the hourly wage = $ /SH

Total Labor Cost per Scheduled Hour = **$ /SH**

Machine Rate

Total Cost per SH = ownership + operating x U + labor = **$ 59.33 /SH**

MACHINE RATE CALCULATIONS
(off-road equipment)

month: April
year: 1990

Description

Machine(make,model,type) Large whole-tree chipper
Accessories or modifications
Engine(Hp,type) 600 Hp diesel

Initial Investment(P) - F.O.B delivered cost = $ 280,000
Economic Life(n) 5 years
Salvage Value(S) 20 % of P = $ 56,000
Scheduled Hours(SH) per Year 2000 hours
Machine Utilization(U) 75 %
Productive Hours(PH) per Year 1500 hours

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 190,400 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 44,800 /yr
Interest 12 %
Insurance 7 %
Taxes 3 %
Overhead 8 %
Total 30 % x AAI $ 190,400 /yr = $ 57,120 /yr

Total Ownership Cost per Year = $ 101,920 /yr

Total Ownership Cost per Scheduled Hour = $ 50.96 /SH

Operating Costs

Repair & Service (% of D) 60 % x (D)$ $\frac{44,800 \text{ /yr}}{1500 \text{ PH/yr}}$ = $ 17.92 /PH

Fuel 600 Hp x 0.023 gal/Hp-hr x $ 1.10 /gal = $ 15.18 /PH

Oil & Lubrication 37 % of the fuel cost = $ 5.62 /PH

Tires $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right)\left(\frac{1.15 \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ -NA- /PH

Total Operating Cost per Productive Hour = $ 38.72 /PH

Labor Costs

Hourly Wage = $ 10.00 /SH

Wage Taxes 25 % of the hourly wage = $ 2.50 /SH

Fringe Benefits 25 % of the hourly wage = $ 2.50 /SH

Total Labor Cost per Scheduled Hour = $ 15.00 /SH

Machine Rate

Total Cost per SH = ownership + operating x U + labor = **$ 95.00 /SH**

MACHINE RATE CALCULATIONS
(on-road equipment)

month: April
year: 1990

Description

Machine(make,model,type) 6 x 4 Tandem axle truck tractor
Accessories or modifications w/ tandem trailer
Engine(Hp,type) diesel

Initial Investment(P) - F.O.B delivered cost = $ 100,000
Economic Life(n) 5 years
Salvage Value(S) 20 % of P = $ 20,000
Scheduled Hours(SH) per Year 2000 hours
Operating Miles per Year 60,000 miles
Operating Miles per SH 30 mi/SH

Average Annual Investment(AAI) = $\frac{(P-S)(n+1)}{2n} + S$ = $ 68,000 /yr

Ownership Costs

Depreciation(D) - straight line method = $\frac{P-S}{n}$ = $ 16,000 /yr
Interest 12 %
Insurance 7 %
Taxes 3 %
Overhead 8 %
Total 30 % x AAI $ 68,000 /yr = $ 20,400 /yr

Total Ownership Cost per Year = $ 36,400 /yr

Total Ownership Cost per Scheduled Hour = $ 18.20 /SH

Operating Costs

Repair & Service (% of D) 50 % x (D)$ $\frac{16,000 \text{ /yr}}{60,000 \text{ mi/yr}}$ = $ 0.13 /mi

Fuel 0.24 gal/mi x $ 1.10 /gal = $ 0.27 /mi

Oil & Lubrication 37 % of the fuel cost = $ 0.10 /mi

Tires $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right) \left(\frac{1.15 \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ 0.10 /mi

Total Operating Cost per Mile = $ 0.60 /mi

Labor Costs

Hourly Wage = $ 10.00 /SH

Wage Taxes 25 % of the hourly wage = $ 2.50 /SH

Fringe Benefits 25 % of the hourly wage = $ 2.50 /SH

Total Labor Cost per Scheduled Hour = $ 15.00 /SH

Machine Rate

Total Cost per SH = ownership + operating x mi/SH + labor = $ 51.20 /SH

Thompson, Michael A.; Sturos, John A.
1991. **Performance of a portable chain flail delimber/debarker processing northern hardwoods**. Res. Pap. NC-297. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 14 p.

Evaluates the performance of a Peterson Pacific 4800 chain flail delimber/debarker processing pole-size hardwoods in northern Michigan. Describes the productivity, cost, and delimbing/debarking quality achieved by the flail.

KEY WORDS: Delimbing, debarking, processors, harvesting, chipping.