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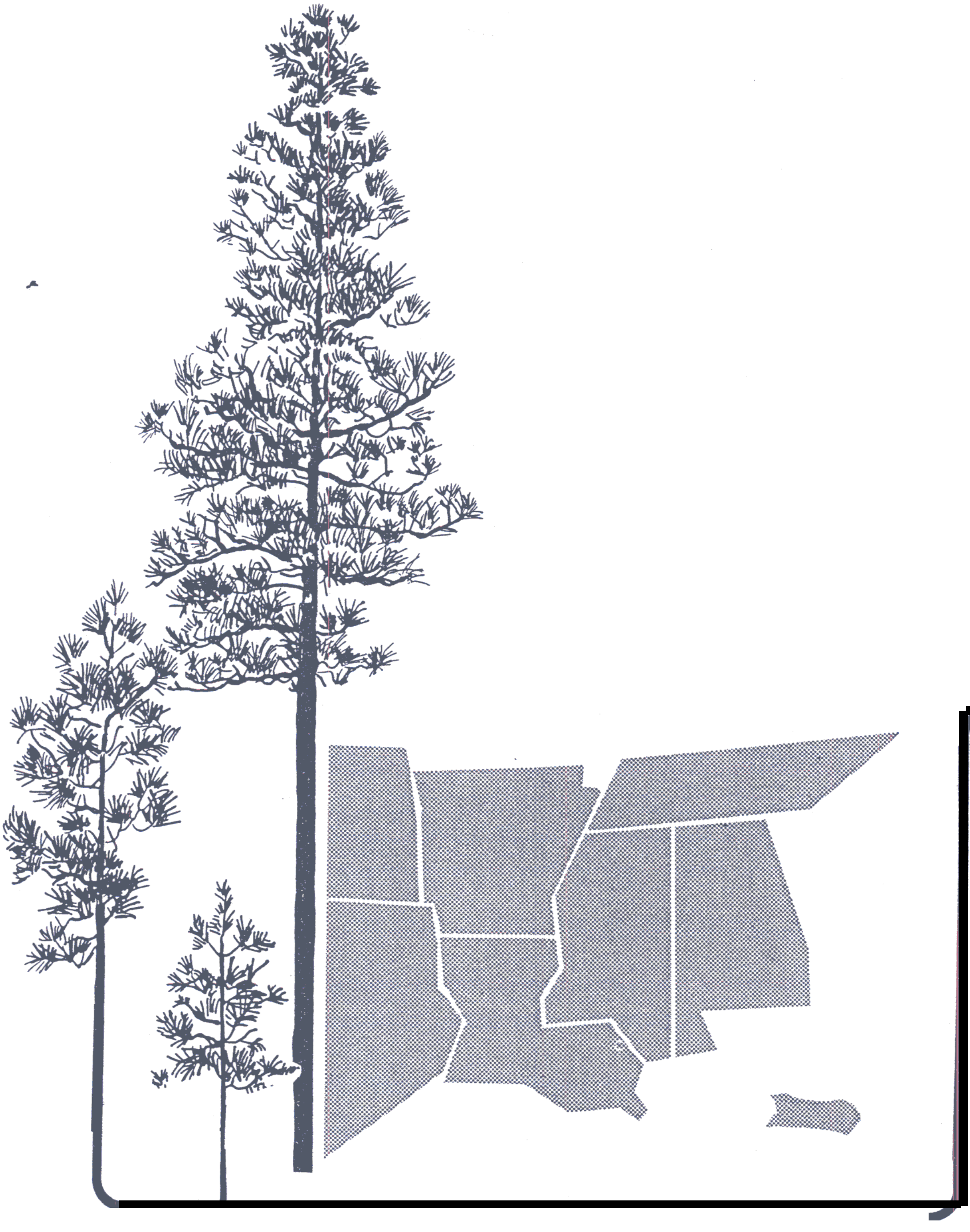

Southern Forest Experiment Station

UTILIZING RESIDUES FROM IN-WOODS FLAIL PROCESSING

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ABSTRACT

A Barkbuster 1100 tub grinder has been employed to process debris discharged by a Manitowoc VFDD-1642. The machine successfully passed the material through a 7.62 cm screen and discharged the reduced debris into a chip van for transport. Fuel production is directly dependent upon the production of clean chips by the flail/chipper portion of the system and the available biomass of the stand. Clean chips were produced at 57 green tonnes/PMH with fuel yields of from 14 to 21 green tonnes/PMH. The usual disposal of flail residues is an additional cost charged to the clean chips; processing turns the residues into a positive cash flow.

INTRODUCTION

The data presented in this paper was obtained from a contract flail/chipping operation on Weyerhaeuser holdings in Southeastern Oklahoma. The tub grinder was modified by the manufacturer to accomodate forestry debris from flail operations. No special changes were required to any of the in place harvesting equipment which consisted of Hydro-Ax feller bunchers, Caterpillar skidders, Log Hog knuckleboom loader, Manitowoc flail, Trelan chipper, and Ford trucks with Nabors trailers. The Barkbuster was located such that the flail conveyor discharged directly into the rotating tub of the machine. The modified blower discharged into the back of a closed top chip van. Some additional landing space was required to situate the chip van properly. The operation continued as normal with the exception of the need to keep a fuel trailer in place when the system was in production.

[1] The use of trade names is not an endorsement by Weyerhaeuser Company, U.S. Forest Service or Mississippi State University.

DESCRIPTION OF THE OPERATION

Stand Information

The site used for the study was 193 ha stand of 16 year old loblolly pine (*Pinus taeda*) on a rolling site with broken short ridges. The stand had been precommercial thinned at age 8 with 682 trees/ha remaining. Average diameter of the trees removed during this first commercial thin was almost 20 cm with an average length of stem 11 m. The stems had branches on 59% of the bole length due to the wide spacing resulting from the early precommercial thinning.

Operation Methodology

Landings are selected based on flat terrain and' proximity to sufficient wood volumes. The operation moves from once a day to once per week. The site is cleared with a crawler tractor and the fuel processor, flail, chipper and loader appropriately placed for skidder and truck access. The trees are cut with a rubber-tired, feller-buncher by means of a hydraulic shear or circular saw head. Bunches are accumulated to allow full loads for the skidders. Medium sized grapple skidders are used to move the trees to the loader at the landing. The loader then feeds small bunches, usually two to four, of trees into the flail where they are delimbed and debarked. The feed rolls, on the flail, move the debarked stem into the chipper feed mechanism for processing into chips which are blown into the waiting van. The debris removed from the stems is deposited into the tub grinder where it is further processed and blown into a fuel van. Both products are then hauled to the Weyerhaeuser Paper Company mill at Valliant, Oklahoma. The one-way haul distance during the study period was 90 km.

Study Methods

Three people were used to assist in data collection.- Information was collected on the physical characteristics of the stems being processed, number of stems per cycle, processing time for each bunch through the flail/chipper/grinder system, productive time, downtime and its cause, and tons per prodcutive machine hour for both chips and fuel.

Machine Specifications and Modifications

The tub and hammermill portion of the fuel processor are originally manufactured as an agricultural machine intended to be powered by a large agricultural tractor. This module is built by Haybuster of South Dakota, Inc., P. 0. Box 909, Aberdeen, South Dakota, USA. The specifications for this original unit are as follows:

Weight	3175 kg
Width	3.35 m
Height	2.74 m
Hammermill length	1.27 m
Hammermill diameter	66 cm
Hammer size	6.35 cm x 19.68 cm x 0.95 cm
Number of hammers	88
Screen sizes	0.48 cm to 10.16 cm
Tub Width	3.35 m
Tub Depth	1.47 M

These units are modified by Lane Equipment Company, 715 Delvan Street, Charlottesville, Virginia, USA. Modifications are as follows:

1. Addition of a towing frame with hitch and engine mount.
2. Installation of a 194 kw John Deere power unit.
3. Replacement of the standard tandem axle suspension with a high ground clearance trailing arm torsion bar tandem suspension.
4. Installation of 0.635 cm thick tub steel tub lining.
5. Installation of a 76 cm diameter heavy duty blower with discharge tube and associated drive mechanism.

These modifications are made for two major reasons: To make the machine self contained and suitable for use in the forest environment and to prevent damage to the machine by the processing of spent flail chain links as they are discharged into the grinder by the flail. Lane Equipment is soon to offer astroloy hammers and screens, as well as the ability to manufacture the entire unit in a more heavy duty manner in a new modern shop facility. There are over 40 of these modified units in operation in various applications in the USA from bark mulch reprocessing to log yard clean up.

STUDY RESULTS

The performance of the fuel processor is directly related to the ability of the flail to provide a continuous flow of debris into the tub. As long as the flail/chipper system is operating the processor can manufacture fuel. However, if the system is down, the processor is also down for lack of raw materials to process. Conversely, if the fuel processor experiences a mechanical failure, it must be quickly removed from the material stream or the chipping operation will be interrupted.

The delays observed during the study are shown in Table 1 for the 13 loads of chips monitored. All times are expressed in minutes.

Table 1 DELAY SUMMARY

Total Time/Load	Tub Delay	out of Wood	Outfeed Limbs	Other Delay	Total Delay	Production Time
minutes						
28.040	3.480	2.419	0.933	0.000	6.904	21.136
48.790	0.000	1.913	0.295	21.408	23.616	25.174
22.300	0.000	2.577	1.792	0.000	4.369	17.931
29.840	0.000	3.295	0.389	0.000	3.684	26.156
38.360	10.743	4.192	0.998	0.000	15.933	22.427
26.750	2.020	2.723	0.000	0.000	4.743	22.007
38.570	3.804	1.390	1.088	0.000	6.282	32.288
37.440	0.000	2.420	0.425	0.000	2.835	34.605
44.090	0.000	1.754	0.291	14.557	16.602	27.488
29.520	0.000	1.460	0.360	0.000	1.820	27.700
36.250	0.000	1.430	0.353	6.460	8.243	28.007
24.960	2.206	1.441	0.000	0.000	3.647	21.313
29.680	0.000	1.431	0.146	7.200	8.777	20.903

Delays caused by being out of wood due to the 340 m skid distance amounted to seven percent of the total, delays from removing debris between the flail outfeed and chipper accounted for two percent of the total time, other miscellaneous delays totaled 11% and delays attributed to the tub grinder amount to five percent of the lost time.

The causes of delays for the tub grinder were a broken drive belt on the hydraulic motor which rotated the tub, failure of the automatic RPM control for tub rotation, loosening of bolts, and dislocation of the tub drive chain by sticks and debris.

During the test period, the machine performed at 95% mechanical availability. Utilization was, however, only 30%, based on the ten hour scheduled workday. This under utilization was applicable to the entire production system and due primarily to not having empty vans available. Many variables caused such problems. The most significant problems were matching trucks to a widely varying haul distance and unloading delays at the delivery point.

Productivity

During the study period 16 loads of clean chips were produced along with eight loads of processed fuel material. The average time to produce one van load of fuel was 56.4 minutes. Fuel yield as a percent of the total volume of chips and fuel produced averaged 26.5% with a minimum of 24.8% and a maximum of 28.9%. The fuel is produced from the conveyor reject debris of the flail. This yield compares favorably with previous flail debris data of 35.5% to 27.0% for similar operations (Watson 1988). The range of yield data can be attributed to the amount of biomass available in the stand in the form of green limbs and needles on the stems. This is, in turn, a function of age of the stand, site, stocking and previous silvicultural history.

Trailer loads of processed fuel ranged from 17.8 to 20.9 green tonnes.

Product Quality

The primary customer for this fuel material has some system constraints which require all fuel to pass through a fuel hog prior to being fed into the boiler infeed system. Because of this, larger size material is acceptable. The processed product, after passing through the tub grinder with 7.62 cm screens, contains particles from 0.63 cm to 23 cm in length. This size gradation has caused no handling problems in the mill conveying system. The fine fraction does tend to burn more quickly in the boiler thus generating heat more rapidly than a larger particle.

Heat yield analysis were conducted on flail debris from loblolly pine (Pinus taeda) trees processed through screen sizes of 5.08 cm, 7.62 cm and 10.16 cm. These were compared to chipping the whole tree, including stem, and also to whole tree hardwood fuel chips. The hardwood consisted of small whole trees and large tops. The species composition was primarily oak (Fagacea quercus spp.). The significantly lower initial moisture content of the hardwood material was due to the fact it had been severed from the stump for some 30 to 45 days during hot weather. As a result of this low green moisture content, it had a higher initial heat yield; but, after drying, the pine and hardwood material were comparable in available heat energy. The results are shown in Table 2. These analysis were conducted according to the Karl Fisher Titration Method, ASTM D240 by American Interplex Corporation Laboratories, 8500 Kanis Road, Little Rock, Arkansas, USA.

Table 2 Heat Content Analysis

		Pine Debris 5.08cm screen	Pine Debris 7.62cm screen	Pine Debris 10.16cm screen	Pine Whole Trees 2.22cm chips	Hardwood 3.05cm chips
Moisture	%	68	66	6i	64	36
Heat Content (Green)	KJ/Kg	1616	1514	1712	1731	2418
Heat Content (Dry)	KJ/Kg	4072	3942	3961	3935	3707

Economic Analysis

This particular fuel processing machine has only been in operation in this application for a short period of time, hence there is no long term cost and maintenance data available. However, by using the data which has been generated thus far, along with information from similar machines in other applications, and our past experience with related machinery, the projected cost of operations can -be-estimated.

An estimated useful life for the machine is three years. Due to limited landing space the machine cannot be used the same number of hours in a year as the remaining chipping system. It is assumed that the machine will be available for operation 60% of the scheduled time and that it will perform at 75% mechanical availability during this operating time. The quoted selling price of this particular unit is $73,000. Ownership costs were calculated to be $16.06/hour scheduled, operating costs of $18.77/hour with labor and overhead an additional $14.21. The results is a total cost of $49.04/hour or a daily cost of $387.15. The daily cost takes into account that ownership, labor and overhead costs are based on scheduled daily hours while operating costs are applied to operating hours only. Details of this estimated cost calculation are found in Table 3.

Based on these cost calculations, and prevailing transportation rates, this machine can produce fuel at a profit even when prices are relatively low. Prices received for such processed fuel material vary from $9 to $22 a green tonne depending upon the geographic location within the continental U.S.

TABLE 3 OWNERSHIP COST CALCULATION

MACHINE DESCRIPTION	BARKBUSTER 1100	RATES
Scheduled Hours/Day	10	
Scheduled Days/Year	200	
Scheduled Hours/Year	2000	
Life in Years	3	
Life in Scheduled Hours	600U	
Hours Available/Day	6	60% Availability
Hours Operated/Day	4.5	75% Utilization
Hours Operated/Year	900	
Purchase Price	$73,000.00	
Taxes	$2,920.00	4% Sales Tax
License and Registration	0.00	
Total Delivered Cost	$75,920.00	
Salvage Value	$10,950.00	15% Salvage
Value to be Recovered by Use	$64,970.00	

Cost of Investment Calculation

Amount Financed	$73,000.00	
Interest Rate		12.5% Interest
Finance Period in Years	3.0	
Total Finance Cost	$18,964.86	
Finance Cost/Scheduled Hour	$3.16	
Insurance Rate	6%	
Equipment Insurance Cost/Year	$ 4,380.00	
Local Millage	0.0502	
Property Tax Cost/Year	$731.92	
SL Depreciation Cost/Year	$20,683.33	
DO6 Depreciation Year 1	$48,666.67	
SYD Depreciation Year 1	$31,025.00	
Total Ownership Cost/Year	$32,117.87	
Ownership Cost/Scheduled Hour	$16.06	

TABLE 3 Continued OPERATING COST CALCULATION

Fuel and Lubricant Consumption	
Fuel Cost $Liter	$0.22
Fuel Consumption L/Opr. Hr.	33.24
Lubricant Cost $/Kg	$0.99
Lubricant Consumption Kg/Opr. Hr.	0.04
Transmission Fluid Cost $/Liter	$1.16
Transmission Fluid Use L/Opr. Hr.	0.00
Engine Oil Cost $/Liter	$0.53
Engine Oil Consumption L/Opr. Hr.	0.08
Hydraulic Oil Cost $/Liter	$0.80
Hydraulic Oil Use L/Opr. Hr.	0.04
Gear Oil Cost $/Liter	$0.40
Gear Oil Consumption L/Opr. Hr.	0.04
Machine Filter Usage $/Opr. Hr.	$0.05
Lubrication Labor $/Opr Hr.	$0.11
Total Fuel and Lube $/Opr. Hr.	$7.62
Tire Costs	
Standard Tires 235/75R16	
No. Tire Required	4
Std. Tire cost $/Each	$95.00
Std. Tire Life in Hours	2000
Std. Tire Cost $/Hr.	$0.19
Hammers	
Cost per Set	$616.00
Life in Hours	325
Cost $/Hr.	$1.90
Repair Reserve $/Opr. Hr.	$4.53
Total Direct Machine Operating Cost	
Dollars/Operating Hour	$18.77

TABLE 3 Continued LABOR AND OVERHEAD COSTS

Labor and Related Costs		
Labor Rate $/Scheduled Hour	$8.00	
Work Comp and Liability Insurance	$2.40	0.0
Social Security	$0.56	0.07
Unemployment Tax	$0.40	0.05
Total Cost/Employee/Scheduled Hour	$11.36	
Crew Size	1	
Total Labor Cost/Scheduled Hour	$11.36	
Transportation Cost		
Vehicle Insurance $/Scheduled Hour	$ 0.00	$0.00
Average Miles to Jobs	35	
Vehicle Cost/Scheduled Hour	$ 0.00	$0.00
Equipment Moving Cost		
Lowboy Cost $/Hour Operated	$35.00	
Hours Required for each Move	3.5	
Moves per Year	22	
Cost/Scheduled System Hour	$ 1.35	
Maintenance Overhead		
Dollars/Scheduled System Hour	$ 1.00	$2,000.00
Office and Administrative Overhead Dollars/Scheduled System Hour	$ 0.50	$1,000.00
Total Overhead	$ 2.85	
Total Cost $/Hour		
Machine Ownership Cost	$16.06	
Direct Machine Operating Cost	$18.77	
Total Machine Cost	$34.83	
Total Labor Cost	$11.36	
Total System Overhead	$ 2.85	
Grand Total Cost $/Hour	$49.04	
Total Daily Cost	$387.15	

CONCLUSIONS

The BarkBuster 1100 successfully processed flail debris at various volumes in an economical manner. Production rates were acceptable to keep pace with the other components of this manufacturing system. Although the trial was conducted with the machine as a part of an integrated system of tree processing, it is possible to follow the flail/chipping operation with the fuel machine as a separate function. This has particular appeal where limited landing space precludes placing all the machines together simultaneously.

Future machines may employ certain mechanical modifications suggested during these tests. Some of these improvements would be a more versatile discharge spout to allow greater flexibility in positioning the machines for more efficient operations, heavier material in the construction of the tub and hammers and heavier gauge material for the fabrication of the discharge spout. In general, the material in the unit is somewhat light for forestry applications and the requirement to handle spent flail chain. Our observations were that an additional 20 to 25 kw of power would be helpful to keep the velocity of the fine material high for proper loading during those periods of peak demand on the hammermill. An interesting alternative design would be to power the entire unit hydraulically and eliminate the current drivelines, chains and belts. Such a design would possibly allow the machine to become more compact. This reduction in size would be a favorable change considering the often limited landing space available.

Although the primary use for this product is fuel for power generation, the machine can process material for use as nursery mulch, potting soil and landscaping. Such operations would provide a more high value product in the near term, while fuel prices remain depressed. As the economics of fuel supply change over time, the value of processed forest biomass will increase and result in considerably more interest in this type of processing. Several manufacturers are showing interest in similar processing units and will have products on the US market with the next year.