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EVALUATION OF A WARATAH HYDRAULIC TREE HARVESTER MODEL HTH 234

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Figure 1 - The Waratah HTH Model 234

ABSTRACT

A Waratah Model 234 Hydraulic Tree Harvester was evaluated processing trees in a landing-based, radiata pine clearfell operation in Kinleith Forest. The operation comprised six manual fallers, two high-drive tractors and a cable skidder for extraction, a rubber tyred loader for fleeting and a hydraulic excavator-based loader for loading trucks.

Estimated productivity was 82m³ per productive machine hour in an average piece size of 1.5m³. A regression equation for total processing time is given. Mechanical availability was 89% and machine utilisation averaged 67%.

The effect of tree form on processing time was tested and was found to have no significant effect ($p > 0.05$). Piece volume had the largest effect on processing time.

INTRODUCTION

Traditionally, the processing (delimbing and log manufacturing), of trees into logs in clearfell logging operations in New Zealand has been a motor-manual operation. During the past five years there have been a number of mechanised processing equipment options trialled. These include : the Harricana Stroke Delimber (Raymond, 1988) a Denis (Moore, 1989), Hahn Harvester (Hill, 1990) and Denis DM3000 Stroke delimber (Robinson and Evanson, 1992).

Some 18 months ago a Waratah Hydraulic Tree Harvester Model 234 (Waratah 234) was introduced into a clearfell operations in Carter Holt Harvey Forests' (CHH) Kinleith Region. In this time, the Waratah 234 has shown itself capable of working in clearfell operations in trees of up to three tonnes, where the average tree size is about 1.5 tonnes.

The objective of this study was to evaluate the performance of the Waratah 234 used as a processor. Specific attention was given to the effect of tree factors, such as volume and tree form on production and subsequent length measurement accuracy.

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THE WARATAH 234

The Waratah 234, made by Waratah Engineering Limited in Tokoroa, is a New Zealand-made single-grip harvester capable of felling and delimbing trees with a large end diameter of up to 65cm. It weighs approximately 3.5 tonnes and requires a minimum 30 tonne excavator base carrier. In this case, the Waratah processor was mounted on an E300B Caterpillar excavator.

Trees are driven through the delimbing knives by three hydraulically powered spiked drive rollers. The feed speed is approximately 3.2m/sec, and the theoretical feed power is three to four tonnes. The hydraulic chainsaw uses 0.404 pitch chain and has a maximum cutting diameter of 70cm with a bar of 1 metre length. A fully computerised length measuring system has 10 different programmable lengths and a diameter sensor.

OPERATION DESCRIPTION

The study was undertaken in a 26 to 27 year old stand of partially thinned radiata pine in CHH's Kinleith Forest.

The Waratah 234 was operated on a single shift basis, using one fully trained operator with more than 12 months' experience. Shift hours varied according to tree volumes to be processed and quota requirements. The loader operator also substituted as a processor operator.

The processing operation was a cold-deck, landing-based system. Trees were manually felled and slovens removed.They were then extracted by either a Caterpillar 518 skidder, a Caterpillar D4 high drive tractor, or a Caterpillar D4 custom skidder and trees were stockpiled beside landings. Trees (butt and top pieces) were mostly extracted butt first, and fleeted so that butts were in line, just off the landing edge. The felling and extraction phase was contracted out to a separate contractor.

Prior to processing, the excavator was positioned with the tracks at right angles to the stack. Trees were then slewed from right to left during the processing operation. Pulp logs were segregated into two fibre density grades and stacked close to the machine, while sawlogs were stacked further away.

Processed logs were intermittently fleeted by a Caterpillar 926E rubber-tyred loader. Once the stockpiled wood had been processed, the Waratah and loader would move to another landing and repeat the process. After processing, loading out was carried out by a Caterpillar EL240B hydraulic loader equipped with a Prentice grapple.

Ten log grades were cut, with a length tolerance of $\pm$ 5cm. All logs were required to be flush trimmed, and were rejected at the mill if there was one stub of more than 5cm diameter and 10cm length left on the log, or more than three stubs of any size protruding by more than 5cm.

Quality control procedures included periodic checking, by both operators, of some log grades determined to be more sensitive to length measuring accuracy (usually longer logs). Marked logs were subsequently reprocessed by the Waratah 234.

STUDY METHOD

A continuous time study was carried out on the Waratah 234 for defined elements of the work cycle. Tree volume was estimated using a one-dimensional volume table derived from trees scaled in the setting. All delays were measured and changes in the method of operation noted.

A sample of 629 logs was measured to assess length measuring accuracy. A tree form index was defined for each tree processed (Table 1).

Table 1 - Tree form classification (after Raymond et al. 1988)

Form Class	Description
1	Straight trees with light branching
2	Trees with moderate sweep and/or heavy branching
3	Forked trees and malformed stems

RESULTS AND DISCUSSION

The operation was studied for three consecutive days, involving 27 hours of continuous timing, during which time 985 full processing cycles were timed. Average piece size processed was estimated at 1.5m^3 (ranging from 0.3 to 3.2m^3) and average extracted tree size was 1.6m^3. Of the pieces processed, 94% were classed as full trees and only 6% were broken top pieces.

When classified by tree form class, 79% were classed as Form 1, 17% Form 2, and 4% were Form 3. Fifty-five pieces were processed per productive machine hour (PMH) producing an estimated 82m^3/PMH. Summaries of time-study results by day, and by combined data are shown in Tables 2 and 3 .

Table 2 - Summary of estimates (by day)

	DAY 1	DAY 2	DAY 3
No. of pieces processed	376	219	390
Study time (hours)	10.27	6.55	10.23
Productive time (hours)	7.19	4.62	6.19
Machine utilisation (%)	70.0	70.5	60.5
Mean piece size (m^3)	1.61	1.52	1.38
Mean no. logs cut per piece	3.4	3.8	3.2
Estimated pieces processed per PMH	52.3	47.4	63.0
Estimated production per PMH (m^3)	84.2	72.0	86.9
Estimated production per day (m^3)	605	333	538

Table 3 - Summary of estimates derived from combined data

No. of pieces processed	985
Study time (hours)	27.05
Productive time (hours)	18.01
Machine utilisation (%)	66.5
Mean piece size (m^3)	1.50
Mean no. logs cut per piece	3.4
Estimated pieces processed per PMH	54.7
Estimated production per PMH (m^3)	82.0
Estimated total production (m^3)	1476
Estimated mean daily production (m^3)	492

Delay free cycle time was 1.11 minutes per processed piece and mechanical availability was 89% with machine utilisation averaging 67%. A summary of cycle time, showing the distribution of cycle elements, is shown in Table 4.

The largest contributor to delay-free process time was the "process tree" element. Accordingly, the "process tree" element, and a combined element of "pick up tree" and "process" ("total process") were further examined for :

(1) effect of piece volume, tree form and sloven cutting time on processing time

(2) effect of stack location and operator variables on processing time

(3) effect of delays to the processor operation caused by quality control procedures, sawhead-related mechanical delays, and loader interference.

(1) Effect of piece volume, tree form and sloven cutting on processing time

Piece volume was found to be a significant predicting variable ($p > 0.05$) for processing time "process tree" and "total processing time" ("pick up tree" and "process"). Tree form class was not significant ($p > 0.05$),

Table 4 - Cycle time summary (minutes)

Element	Number of Cycles	Mean per Occurr-ence	Mean per cycle	Range (±)*	% of total
Pick up tree	919	0.23	0.22	0.06	13
Process tree	963	0.67	0.66	0.03	39
Align stack	141	0.63	0.09	0.02	5
Sort	48	0.96	0.05	0.02	3
Move	47	1.95	0.09	0.06	5
DELAY- FREE TOTAL			1.11		
Personal delay	19	12.26	0.24		14
Operational delay	117	1.41	0.17		10
Mechanical delay	20	7.21	0.15		11
TOTAL CYCLE TIME			1.67		

* Range for 95% confidence Interval

possibly because there were few (4%) trees in the Form 3 class and differentiation of trees into Form 1 and 2 classes was found to be difficult. Due to the silvicultural regime practiced (relatively high stocking until clearfell) the trees processed were generally tall, straight and lightly branched. The cutting of slovens was also found to have no significant effect on "process tree" time ($p > 0.05$).

The following equation and graph (Figure 2) demonstrate the relationship between "total processing time" ("pick" and "process") and piece volume.

Total Processing time (minutes)
= (36.9 +(34.8 * Volume (m^3))) / 100

($r^2 = 0.38$)

For example, for a piece of 2.0m^3 volume

Total Processing time (minutes)
= (36.9 + (34.8 * 2.0)) / 100

=106.5

= 1.06 minutes

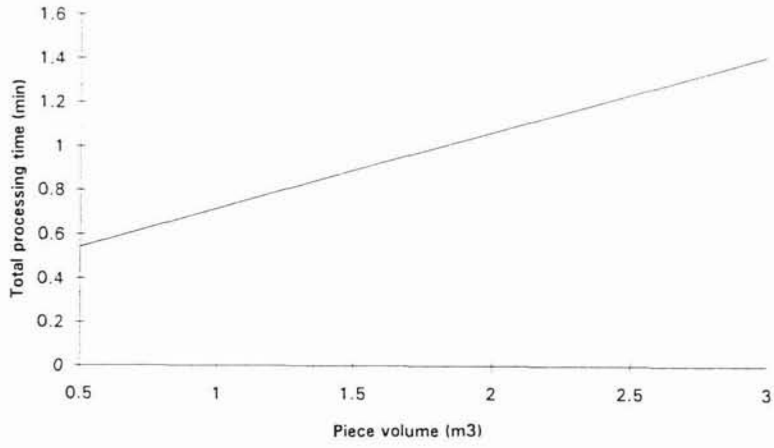

Figure 2 - Total processing time (minutes) versus piece volume (m^3)

(2) Effect of stack location and operator variables on processing time

Mean values of "Process Tree" time were significantly different for each day's study. This variation could not be wholly explained by the variation in mean tree or piece volume. Two possible reasons for this are considered to be stack location, and operator performance. The operator commented that processing was faster when stockpiles enabled downhill processing (that is, movement of the tree through the processing head was downhill to some degree). Some time would often be taken to align the trees to be picked up, and so try to prevent heads binding, before processing a series of trees from a stockpile.

Operator-related factors are often responsible for variation in machine performance. Performance of individual operators can also differ markedly. For instance, Raymond (1988), found that the operator of a Harricana delimber had a daily production variation of up to 23%. Part of the daily variation in processing time observed in this study may be due to this phenomenon.

(3) Effect of delays to processor operation caused by quality control procedures, sawhead maintenance, and loader interference

The lengths of some log types were systematically checked and logs were recut if found to be out of specification. This procedure involved both operators, with a resulting reduction in time available for productive work. The time delay caused by quality control was attributed to operational delay.

On day 1 of the study for instance, 30.2 minutes were spent checking and recutting logs, and 39 logs were reprocessed. This constituted 3% of the total number of logs cut.

If a machine utilisation factor (0.73) is applied to the delay time, this results in 22.0 minutes of productive time lost. In that time, an additional 19 tree lengths could have been processed, equating to a production loss of $31m^3$.

Mechanical delay accounted for 11% of total cycle time. Of this, 34% involved sawhead maintenance. Loader interference was minimal, comprising 10% of all operational delays.

Travel Between Landings

The "move" element comprised 5% of total cycle time, and 8% of productive cycle time. Travel between landings, comprised 77% of the total "move" time, averaging nine minutes per occasion. Average travel speed was 2.3 km/hr or 39 metres per minute over an average distance between processing sites of 390 metres.

Most travel was by road with only two movements by cutover track. Track travel speed was 1.8 km/hr. During the course of the three day study, four landings and two other processing sites were utilised. Of these, two were used twice.

Length Measurement

Quality control of logs produced was an important feature of this operation. Both the Waratah 234 operator, and the loader operator systematically sampled processed logs, and reprocessed where necessary, to maintain quality standards.

The two operators measured every log produced in the Q9.8 (9.8 metres) grade, and a random selection of three other grades

Table 5 - Log measurement results by grade

Log type	Number of logs measured	Mean length (m)	Standard deviation (cm)
F 4.9	56	4.89	9.44
F 6.1	120	6.11	5.01
FA 4.1	61	4.11	4.76
T 8.6	21	8.60	2.48
T 9.8	96	9.80	4.89
Q 9.8	261	9.79	6.07

on the stacks, to ensure that the percentage of logs out of specification was kept at an acceptable level (for the company, this meant at levels comparable to motor-manual processing). The specifications aided this process as recutting to the next grade usually involved less than 600mm wastage.

The length measurement equipment was frequently calibrated, as the causes of inaccuracies are still unclear. The scale factor (or relationship) between measuring wheel circumference and distance, was set by the operator (via the computer) by comparing computer length readings with tape measurements on a delimbed log. A total of 629 logs were measured to assess the length aspect of log quality.

The results of the measurement of the sampled log types are presented in Table 5. A large standard deviation indicates more variation in measured length. However, results derived from larger numbers of sample logs, such as Q 9.8s give a more reliable indication of cutting accuracy than from smaller samples such as the T 8.6 logs measured. The range of lengths for one specified length or log type is illustrated in Figure 3.

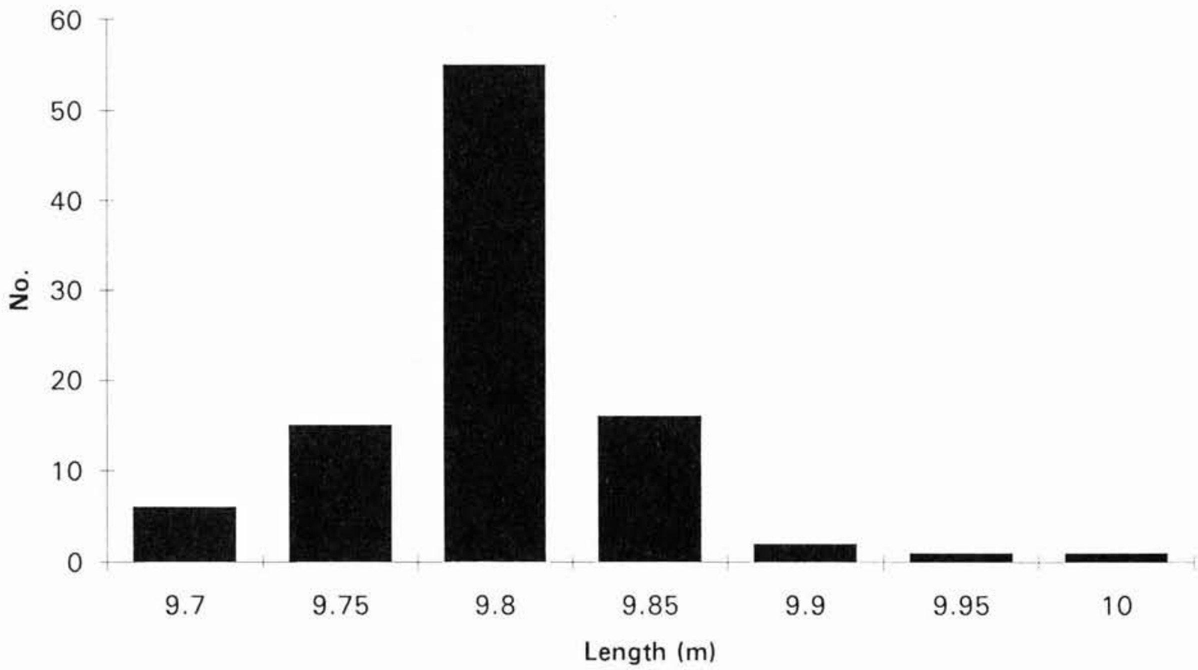

Figure 3 - Frequency distribution of lengths for T9.8m logs

Table 6 - Logs out of specification (as percentages) for different tolerances

Log type	Tolerances (cm) ±1	±2	±3	±4	±5	±6	±7	±10	±15
FA 4.1	57	39	28	21	13	8	8	3	3
F 4.9	66	36	27	14	13	12	11	3	3
F 6.1	77	56	28	19	12	8	7	2	2
T 9.8	62	45	29	23	19	15	10	3	1
Q 9.8	78	60	40	26	20	17	13	5	2

Log customers are concerned that suppliers reduce the percentage of logs whose lengths lie outside the range of lengths specified in each grade. However, the issue of acceptable tolerances is often a sensitive issue. The percentage of logs falling out of specification for different tolerances is shown in Table 6. For example, at a tolerance of ±5 cm, logs of type "FA 4.1" were 13% out of specification for length.

Longer logs (T and Q grades), were found to have more logs out of specification (at ± 5 cm) than shorter, F grade logs. It would appear that measuring accuracy declined (that is, variation increased) with the increasing length of the log measured. However, two-sample t tests showed no significant difference (p0.05) between variation from specification values for different log grades, lengths or small end diameters.

If length measuring accuracy is to be improved, efforts must be made to isolate the significant mechanical, tree and methodological factors causing the variation in lengths, and address each separately.

COSTING

A Waratah 234 and base were costed using a standard LIRO format (Wells 1981). With a capital cost of $620,000 and a residual value of $250,000 at 8,000 productive hours, a base cost of $135 per hour, or $950 over a seven hour day was calculated. This excludes operator wages, transport, operating supplies, overheads and profit.

CONCLUSIONS

Piece volume was found to be a significant ($p > 0.05$) predicting variable for the logarithm of "process" time and "total process " time ("pick up tree" and "process"). Tree form class was found to be non-significant ($p > 0.05$), possibly because of the uniformity of the crop and the capabilities of the processor.

A higher percentage (19% to 20%) of longer length logs were out of specification than short logs (8% to 12%). However, no significant relationship ($p > 0.05$) between the differences from specification value, and log grade, length or small end diameter, was found.

Quality control measures, checking lengths, for this operation comprised approximately 7% of productive time during the study. Lost production due to this procedure was estimated to be 31 m^3/day.

The Waratah 234 produced an estimated 82m^3/PMH in a mean piece size of 1.5m^3. Mechanical availability was 89% and machine utilisation was 67%.

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The costs stated in this report have been derived using the procedure shown in the LIRA Costing Handbook for Logging Contractors. They are an indicative estimate only and do not necessarily represent the actual costs for this operation.

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