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# A GRAPPLE HARVESTER/WHEELED LOADER SYSTEM FOR CLEARFELL RADIATA

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*Figure 1 - Waratah Mark 4 Grapple Harvester*

*ABSTRACT*

*An investigation was undertaken of a system using a Waratah grapple harvester to fell and delimb small piece size radiata pine clearfell on flat country. The harvester felled and delimbed approximately 125 trees per productive machine hour (PMH). Extraction was by wheeled front-end loader to the landing. The wheeled loader extracted bunches of tree-length wood an average distance of 80m, and loaded five to six trucks per day. The study indicated that system productivity was around 180 tonnes of wood per day.*

## INTRODUCTION

In 1987, Waratah General Engineering Limited of Tokoroa developed a heavy duty grapple processor (Duggan, 1988). A further development from Waratah was the hydraulic tree harvester (HTH) which featured fixed-boom mounting, and a purpose-built boom (Raymond, 1988).

Subsequently, the fixed mounting design of the HTH head was altered to incorporate a hydraulic rotator mount and the Waratah Mark 4 3-roller grapple harvester was developed.

As of early 1991, 44 harvester and processor units have been manufactured and sold, mainly to Australia and Canada.

In September, 1988 Les Gilsenan, an innovative Canterbury logging contractor, purchased a Waratah harvester. The harvester was used to fell, delimb and stack trees from clearfell stands in Eyrewell Forest. A Furukawa wheeled front-end loader was used to extract the piles of processed wood to the skid, a method of extraction Les Gilsenan has been using successfully since 1976 (Gilsenan 1986).

*ACKNOWLEDGEMENTS*

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## MACHINE DESCRIPTIONS

### Waratah Harvester

The Waratah grapple harvester head has a double-acting shear for felling, and two moveable knives and one fixed knife for delimbing. Trees are driven through the knives by three spiked feed rollers.The maximum tree capacity for felling is 46cm butt diameter. The required hydraulic flow is 200 *l*/min at 250 Bar. The minimum power requirement of the base carrier is a 75kW machine.

The harvester head was mounted on a Hitachi EX200 carrier, which is powered by a 92kW Isuzu diesel engine (Figure 1). The carrier has a maximum lifting capacity of 2.4 tonnes at maximum reach of around 8.0m. Given the weight of the harvester head (1450 kg), the maximum tree size, at full reach is around 1.0 tonne.

### Furukawa Wheeled Front-End Loader

The loader used was a Furukawa FL 230-I rubber tyred front-end loader, powered by a 119kW Mitsubishi diesel engine (Figure 2). The rated lifting capacity of the loader was 4.5 tonnes. The loader was fitted with

*Figure 2 - Furukawa FL230 Wheeled Loader*

16-ply tyres, inflated to 65 psi pressure. Modifications to the loader for in-bush extraction included underbody guarding, radiator guarding, and relocation of the lights and air-conditioning unit (Gilsenan, 1986).

## SYSTEM OPERATION

The study area was an eighteen year old "catch crop" stand in Eyrewell Forest. Details of the stand are outlined in Table 1. The "catch crops" are untended stands designed to increase the resilience of the forest against north-westerly gales common in Canterbury. The "catch crop" is planted at eight-yearly intervals in 300m wide strips perpendicular to the prevailing wind. The pulpwood arising from the clearfelling operation supplied Canterbury Timber Products Limited's medium density fibreboard (MDF) mill at Sefton. The Waratah operator was experienced and had operated this machine since it was purchased in 1988.

*Table 1 - Stand Details*

| | | |
|---|---|---|
| Stand age | (years) | 18 |
| Stocking | (stems/ha) | 1342 |
| Mean DBH | (cm) | 22.1 |
| Mean piece size | ($m^3$) | 0.236 |

The normal work method involved the Waratah harvester felling a strip of trees seven to eight rows wide parallel to the road for a distance of approximately 300m. From experience, the operator had found seven to eight rows to be the optimum strip width to enable all trees to be reached from one machine position.

Working systematically across the felling face the harvester felled trees into the stand, slewing the tree away from the stump, and immediately started processing the tree. Topping the tree was achieved by tilting the harvester head to break the top from the tree at a small-end diameter of 10cm. The processed tree lengths were stacked in rough piles to either side of the base carrier for extraction by the wheeled loader.

Since the strips were 300m wide, the maximum haul distance for the loader was approximately 150m. From the landing, the loader cleared a path to the felling face where the harvester was working. After loading an optimum grapple load (approximately 20 pieces) by picking up several bunches of trees, the loader travelled back to the landing. The processed tree-lengths were then fleeted into stacks of longs and shorts for loadout.

**RESULTS AND DISCUSSION**

System productivity of the operation over the long term has been 6 truck loads of pulpwood per day. At an average of 30.0 tonnes per load, this is equivalent to 180 tonnes per day.

**Waratah Harvester**

The total duration of the study was 15.95 productive machine hours (PMH), during which time 1690 trees were felled and processed. Detailed timing was carried out for the harvesting of 1472 trees.

The average productive cycle time was 0.48 minutes per tree (Table 2), which is equivalent to a processing rate of 125 trees per PMH. Given the average tree size of 0.24 $m^3$, volume productivity averaged approximately 30 $m^3$/PMH.

*Table 2: Waratah Harvester Work Cycle*

| Element | No. of Observations | Mean per Observations (mins) | Mean per Cycle (mins) | % of Productive Cycle |
|---|---|---|---|---|
| Move | 259 | 0.184 | 0.032 | 6.7 |
| Position | 1472 | 0.128 | 0.128 | 26.6 |
| Fell | 1472 | 0.103 | 0.103 | 21.4 |
| Process | 1472 | 0.198 | 0.198 | 41.2 |
| Travel | 3 | 0.883 | 0.002 | 0.4 |
| Fell Unmerch. | 180 | 0.149 | 0.018 | 3.7 |
| Productive Cycle | | | 0.481 | 100.0 |
| Mechanical Delay | 3 | 14.39 | 0.029 | - |
| Operational Delay | 6 | 0.49 | 0.002 | - |
| Personal Delay | 4 | 23.31 | 0.063 | - |
| Total Delays | | | 0.094 | - |

Processing accounted for 41% of the total productive cycle. Regression analysis indicated that tree size had little effect on net processing time (position, fell and process).

Tree form had a greater influence on processing time than tree size. Tree form was ranked subjectively, according to the following form classification:

*Table 3: Variation of Processing Times Between Form Classes*

| | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| Sample Size | 889 | 74 | 92 |
| Processing Time | 0.178 | 0.303 | 0.314 |
| Butt Diameter (cm) | 21.8 | 23.6 | 23.4 |

*Form Class 1 - Straight, small branching habit*

*Form Class 2 - Straight, slight sweep, large branches*

*Form Class 3 - Malformed, double leaders*

The branching of the radiata pine stand was only light. Only 7% of the stand was classed as having heavy branching habit (Form Class 2). Only 9% of the trees processed were classed as malformed (Form Class 3).

Table 3 shows the effect of tree form on processing time. A significant difference (at the 95% level) was found between the processing time of trees with good form and those which were heavily branched or malformed. Therefore for high productivity, straight, normal form trees are more suited to the harvester. There was no significant difference between the processing times of trees of Class 2 and Class 3.

The Waratah does not delimb the bottom 0.6m of the tree. However, in the study stand it had little difficulty in breaking the bottom branches of each tree to position the head for felling. In older lower-stocked clearfell stands the branch size at ground level may limit access of the harvester head to the tree. In these circumstances, mechanical delimbing may not be effective unless the first metre of the tree has been pruned or trimmed manually. In this operation, trees occasionally had branch stubs in this critical area. The loader driver usually trimmed these branches at the landing. However, this did not affect the overall productivity of the operation. In general, the quality of the delimbing was of a standard suitable to meet the mill's specifications.

The advantages of a grapple harvester include the potential to reduce the cost of processing small diameter wood and also of bunching for the extraction phase. The Waratah harvester would be suitable in a grapple skidder system.

**Furukawa Wheeled Loader**

The loader was studied for a total of 16.46 scheduled hours (81 cycles), during which time it extracted 371.2 tonnes of wood and loaded 11 trucks. The net extraction cycle time averaged 3.8 minutes per load over haul distances averaging 80m (10-148m range). Operational delays such as waiting for the processor, clearing slash and fleeting on the skid were added to this net figure to give a total extraction cycle of 8.6 minutes per load. Load volumes averaged 4.6 $m^3$ per load, resulting in extraction productivity, of 32.1 $m^3$/PMH (Table 4). The loader travel speed averaged 5.5 km/hour empty, and 3.8 km/hour loaded.

The stoney soils and flat terrain of Eyrewell Forest provided ideal operating conditions for the wheeled loader extraction system. Where wet conditions prevail, one option would be to operate the loader with tyre chains to increase the loader's tractive capacity.

Truck loading averaged 17.13 minutes per load, for an average load of 30.07 tonnes. This is equivalent to an average truck loading productivity of 105.3 tonnes per PMH, or 0.57 min/tonne.

*Table 4: Furukawa Loader Work Cycle*

| Element | No. of Obser-vations | Mean per Observations (min) | Mean per Cycle (min) | % of Total Extraction Cycle |
|---|---|---|---|---|
| Travel Empty | 81 | 0.899 | 0.899 | 10.5 |
| Load 1 | 81 | 0.628 | 0.628 | 7.3 |
| Move | 38 | 0.390 | 0.183 | 2.1 |
| Load 2 | 38 | 0.859 | 0.403 | 4.7 |
| Load 3 | 11 | 0.721 | 0.098 | 1.1 |
| Travel Loaded | 81 | 1.319 | 1.319 | 15.3 |
| Unload | 81 | 0.243 | 0.243 | 2.8 |
| Net Extraction | | | 3.773 | 43.8 |
| Operational Delays: | | | | |
| Wait Processor | 15 | 1.777 | 0.329 | 3.8 |
| Track | 13 | 0.567 | 0.091 | 1.1 |
| Clear Slash | 40 | 0.534 | 0.264 | 3.1 |
| Pick up Logs | 4 | 0.324 | 0.016 | 0.2 |
| Fleet on Skid | 81 | 4.129 | 4.129 | 48.0 |
| Total Extraction | | | 8.602 | 100.0 |
| Truck Loading | 11 | 17.13 | 2.326 | - |
| Personal Delay | 10 | 8.785 | 1.085 | - |
| Mechanical Delay | 2 | 7.410 | 0.183 | - |
| Total Cycle | | | 12.196 | |

Extraction productivity (in $m^3$/PMH) including fleeting was derived from the net extraction cycle time (including allowances for delays and fleeting), and load size data. The relationship between extraction productivity, load size and haul distance was:

*Productivity ($m^3$/PMH) = (5.8 x Load Volume ($m^3$)) - (0.05 x Haul Distance (m)) ($r^2$=72%)*

The two important factors affecting productivity (load size and haul distance) were examined to see which factor had a greater influence on loader productivity (Table 5).

The effect on loader productivity of a 50m decrease in average haul distance was equivalent to an increase in load size of only 0.4$m^3$ (2 pieces) over the same haul distance. For example, with a load size of 4.0$m^3$, the effect of shortening the haul distance from 150m to 100m (increasing productivity from 15.7 to 18.2 $m^3$/PMH) is less effective than maintaining the haul distance at 150m, and increasing the load size to 4.5$m^3$ (18.6 $m^3$/PMH).

*Table 5: Effect of Load Size and Haul Distance*

| Load Size ($m^3$) | Haul Distance (m) | Productivity ($m^3$/PMH) |
|---|---|---|
| 3.5 | 100 | 15.3 |
| | 150 | 12.8 |
| | 200 | 10.3 |
| 4.0 | 100 | 18.2 |
| | 150 | 15.7 |
| | 200 | 13.2 |
| 4.5 | 100 | 21.1 |
| | 150 | 18.6 |
| | 200 | 16.1 |
| 5.0 | 100 | 24.0 |
| | 150 | 21.5 |
| | 200 | 19.0 |

## MACHINE AVAILABILITY AND UTILISATION

During this short-term study, the utilisation of the Waratah harvester was measured at 83.7% of scheduled "on-job" time, which is higher than normally expected. Of the delays "smoko breaks" were the largest, accounting for 11% of total time. Mechanical delays (5.0%) involved preventative maintenance checks and lubrication.

A long term study of Les Gilsenan's Waratah harvester during 1990 showed that mechanical availability averaged 86.3%, and overall machine utilisation averaged 79% of total scheduled hours (range 69-87%). This was attributed to the rigid maintenance schedule to which the operator adhered (Jensen, 1990).

Loader utilisation over the two shifts of the study was 89.6%. This was comprised of extraction and fleeting (70.5% of total time), and truck loading (19.1% of total time). Personal delays accounted for 8.9% , and mechanical delays constituted only 1.5% of total time.

According to the contractor, repairs and maintenance on both the harvester and the loader have been low. Tyre wear on the loader has not been excessive given the operating conditions, with two new tyres required over two years of operation. This is mainly a result of the careful operating techniques used by the loader operator.

## SYSTEM COSTING

Both machines in the system were costed using the standard LIRA costing format (Wells, 1981). Capital cost for the Waratah harvester head with felling shear is $174,000 giving a total cost for the unit mounted on a Hitachi EX200 of $334,000. The capital cost used for the Furukawa 230 loader was $185,000.

*Table 6: System Costing ($/day)*

| | |
|---|---|
| Furukawa Loader | 401.00 |
| Waratah Harvester | 861.00 |
| Labour (2 operators) | 300.00 |
| Vehicle | 40.00 |
| Overheads (2%) | 32.00 |
| Total Daily Cost ($) | 1634.00 |

## CONCLUSION

The grapple harvester/wheeled loader combination is an efficient system for harvesting the Eyrewell Forest "catchcrop" stands. The Waratah harvester was capable of high productivity, felling and processing. Tree size and form were well suited to mechanised harvesting. The Waratah was operated very efficiently by an experienced machine operator. Precise movement of both the harvester head and the base carrier meant that it would be very difficult to increase productivity through reducing the total work cycle. The Waratah harvester may not be suitable in heavily-branched malformed radiata pine stands more common in the rest of New Zealand.

Although the stoney soils of Eyrewell Forest provided ideal operating conditions for loader extraction, this extraction technique could be just as effective in other forests where topography is relatively flat such as Kaingaroa Forest. The costs of loader extraction against conventional skidder extraction under these conditions would be competitive. Using one machine to extract, fleet and load trucks has distinct advantages in terms of capital outlay, repairs and maintenance costs and machine utilisation.

Looking at the system, two machines and two operators produced as much as two machines and nine men in a conventional operation (6 fallers, 2 machine operators and one skidwörker). Further to this, fully mechanising the operation has allowed the two machines to work extended hours, or to be double shifted when increased wood flow has been required.

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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 only an indicative estimate and do not necessarily represent the actual costs for this operation.*

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