Comparison of different flail chains operating in Eucalyptus globulus plantations in Western Australia

Rick Mitchell[1]

[1]*Australian Forest Operations Research Alliance (AFORA), University of the Sunshine Coast*

Introduction

A range of flail chains are currently used to debark plantation-grown Eucalyptus globulus (blue gum) at roadside. New types of drum flail chains are being developed to improve debarking, limit wear and extend the life of the chains. There is currently a lack of information on how the use of different chains affects cost, machine productivity and wood recovery. This project investigated the debarking productivity, cost and wood recovery of different types of flail chain. The study took place over two periods, February and March 2012 and August 2012. The objectives were to compare the performance of five different flail chains operating in blue gum plantations in terms of:

wear (weight change, length change, chain link losses)
fuel use per chain type
percentage of bark in the woodchips
the productivity of the chains
the costs associated with using each of the 5 flail chains

Study area and method

The study was conducted in the south-west of Western Australia in two separate plantations. The first was located near Rocky Gully with a total area of 141 ha and a yield of 173 m3/ha. The second was located near Mt Barker with an area of 362 ha and a yield of 143 m3/ha.

The harvesting system consisted of a Tigercat 855C feller-buncher, two skidders (a Tigercat 630C and Tigercat 630D) delivering whole trees to a Husky Precision flail 2300-4 (580hp) and Husky Precision chipper 23-66 (875hp) (Figure 1). The trees were flailed and chipped directly into trucks and delivered to the Port of Albany.

Figure 1. Husky Precision flail and chipper loading truck

Five different flail chain types were evaluated:

1. Function Oval
2. RUD
3. Peerless
4. Function square Type 1 (3 oval and 5 square chain links)
5. Function square Type 2 (1 oval, 6 square and 1 oval chain links)

The flail had a series of 4 flail drums. In this study only the first two drums (those nearest the infeed) were assessed as they do most of the debarking. On these two drums there were six rows of seven holes slightly offset from each other, into which a chain was attached by a rod (Figure 2). A single chain per hole was used and assessed during this study (42 chains per drum for a total of 84 chains). The last two drums are considered to be 'sweepers' as they do not carry out as much of the debarking. The sweepers were inspected each day to ensure no links were missing and were changed if any links were missing.

Figure 2. Illustration of drum design

Figure 3 shows how each chain length was allocated to a row (A, B, C, D, E & F) on the flail drum and hole position (1–7). The chains were measured and recorded prior to being put into these selected positions on the drum, and were wired onto pieces of wood when not in use to keep track of each chain's position. The flail drum rod on row A was also painted to enable each chain to be placed back in that exact same position (i.e. A-1) for each new shift.

To eliminate the differences in physical tree characteristics (i.e. tree size), operational variation (i.e. rpm of flail, infeed speed) and operator influence, the chain type used was different for each shift (Table 1). Each chain type was run in the flail for a whole shift (day) before being removed and replaced with a different chain type. This process occurred over four or five days to ensure the total tonnes processed by each chain type were approximately equal. Daily production varied from day to day due to mechanical and operational delays. On some days it was not possible to change the chains at all due to operational reasons.

Table 1. Number of different shifts (days) of chain use

Chain type	Number of shifts chains used
Function Oval	5
RUD	5
Peerless	4
Function square Type 1 (3 oval, 5 square)	4
Function square Type 2 (1 oval, 6 square, 1 oval)	4

Figure 3. Chain location, storage and installation

Data collection

Each chain was measured in the following ways prior to commencing each shift:

- narrowest reading of chain thickness (mm) of the 7th and 8th link (from the flail drum)
- length of each chain
- weight and position of each individual chain
- number of links on each length of chain.

Detailed time and motion studies were conducted to calculate the productivity of the flail for each chain type used. A total of 173 truckloads were evaluated. The weight of each truckload of woodchips in green metric tonnes (GMt) was recorded and the productive machine hours minus all delays (PMH0) was used to calculate the productivity of each chain type. During the trial the daily fuel use of the chipper and the flail was recorded from each machine's onboard computer.

Results

Costs of chain

Flail chain is purchased by weight (i.e. dollars per kilogram), therefore weight per chain length is an important factor when deciding to purchase chain. In terms of cost per kilogram, RUD was the most expensive and Function Oval the cheapest, but because Peerless was the lightest chain, it worked out the cheaper per length (Table 2).

Table 2. Purchase price, start and finish weight and cost per chain type for two flail drums

Chain Type	Start weight (kg)	$/ length	Drums cost (84 chains)	$/kg	Finish weight (kg)	Weight (kg) loss	$ lost	% loss in weight
Peerless	195.6	$9.32	$782.88	$4.00	184.7	10.91	$43.67	5.9%
RUD	207.1	$13.55	$1138.20	$5.49	191.2	15.98	$87.82	8.4%
Function Type 1	215.2	$11.85	$995.40	$4.62	206.6	8.60	$39.76	4.2%
Function Oval	205.0	$9.60	$806.40	$3.93	189.9	15.08	$59.32	7.9%
Function Type 2	232.2	$11.85	$995.40	$4.29	198.4	33.79	$144.85	17.0%

Tonnes processed

The total delivered tonnes (GMt) by each chain type is presented in Table 3.

Table 3. Tonnes delivered per chain type

Chain type	Deliveries March (GMt)	Deliveries August (GMt)	Total deliveries (GMt)
Peerless	1370.0	333.4	1703.5
Function Type 1	1456.0	294.3	1750.3
Function Oval	1432.7	384.1	1816.8
Function Type 2	1442.7	437.4	1880.1
RUD	1422.6	467.1	1889.7
Total	**7123.9**	**1916.3**	**9040.3**

Chain length gain and diameter loss

The length of each chain type was measured (to the nearest mm) prior to each shift, and at the end of each day to determine the gain in chain length. The narrowest chain thickness (mm) of the 7th and 8th link was also measured and recorded. Table 4 shows the length and diameter gains and losses for each chain type.

Table 4. Loss of diameter per link and gain in length for each chain type

Chain type	% gain in length per link	Gain in length (mm)	% loss of dia per link	Loss of dia per link (mm)
Function Oval	3.9%	2.09	19.3%	2.63
Function Type 1	4.8%	2.52	14.7%	2.03
Function Type 2	4.8%	2.73	25.9%	3.34
RUD	5.3%	2.86	23.2%	3.11
Peerless	6.3%	3.31	28.8%	3.64

Link loss

The number of links lost was recorded after each shift. Table 5 shows the total number of links lost for the duration of the study. The Function Type 2 chain lost twice as many links as Function Oval and RUD. Function Type 1 performed very well, with a loss of only one link for the whole study period.

Table 5. Number of links lost per chain type for the whole study

Chain type	Links lost
Function Type 1	1
Peerless	6
RUD	21
Function Oval	21
Function Type 2	43

Figure 4. Chain measurement station

Productivity

The productivity of each chain type is presented in Figure 4. There was no significant difference in the productivity of the flail and chipper among chain types. The chipper was moved to four different sites while working in the plantation near Rocky Gully and one site in the plantation near Mt Barker. There was also no significant difference in the productivity of the flail and chipper among chipper sites and chain type. Peerless was the best performer in terms of productivity and was also cheaper. A fixed cost of $520 per PMH0 was applied to each shift to compare production cost ($/PMH0) of each chain type (Figure 5).

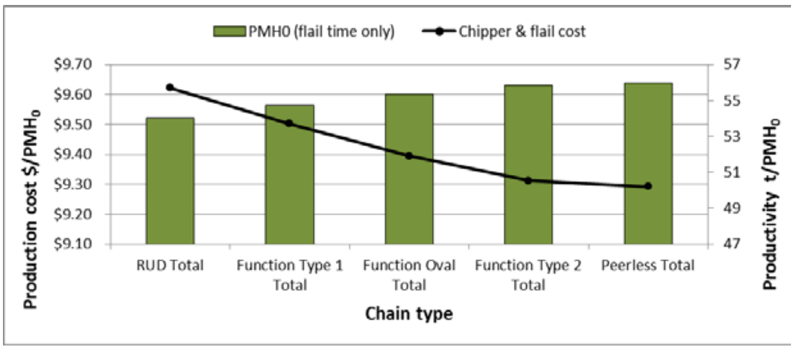

Figure 5. Chipper and flail production cost and productivity

Bark

For each truckload a 2 kg sample of chips was collected and weighed, either at the port facility or in the field, to determine the bark content. The bark content allowance was 0.5% of the delivered weight. All chain types performed very well for bark removal with the worst result being half the allowable amount at 0.25%

(Table 6). The average bark content percentage result for the flail and chipper studied over the previous twelve months was 0.44%, which shows a much higher amount of bark retained than during this study. This could be because the operators were aware of bark samples being taken more regularly than normal during the study which may have influenced their behaviour in relation to the method or speed of tree in-feed into the flail. That the chains used during the study were all new may also have been a factor in the better-than-average performance of all chain types in terms of bark removal.

Table 6. Combined port and field bark sample results

Chain type	Ave bark content %
Function Type 2	0.16%
Function Type 1	0.20%
Peerless	0.22%
Function oval	0.22%
RUD	0.25%

Fuel use

Fuel use was recorded each day for the flail and the chipper, and divided by the tonnes delivered to determine the fuel use per GMt. Fuel use was then converted to fuel cost using $1.50/L (Figure 5). The amount of fuel used was related to the weight of the chains: Function Type 2 was the heaviest chain and had a higher fuel cost, while the Peerless chain was the lightest and had the lowest fuel cost. RUD chain was slightly lighter than Function Type 1 chain and had the same fuel use per GMt produced.

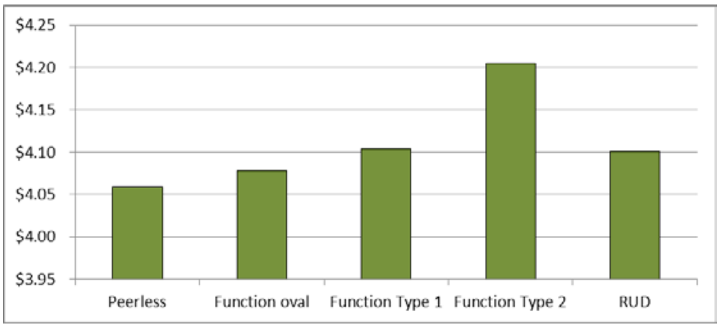

Figure 6. Flail and chipper fuel cost per GMt

Discussion

The study was run over an extended period of four weeks. Some types of chain lengths within chain types still had productive life, while others would no longer be used. It is typical practice for chains to be moved on the drums, i.e. outside chains moved to the middle of the drum and chains “end for ended” (turning the chain and attaching the worn end into the drum rod) however during this study the chains remained stationary. All the chains performed well in some areas. The Function Type 1 performed well in all areas (lowest weight loss, lowest loss of link diameter and the loss of only one link); however, the design does not allow for the practice of ‘end for ending’ like the other chains which have an oval link on both ends. Although it appears to have a longer life resulting in less frequent chain changes, it cannot be recycled as is typical for other types of chain with oval on both ends.

Take-home messages

- There were no significant differences in the productivity of the flail and chipper between the chain types.
- All chains removed bark to a high level and well within the maximum bark content percentage specification.
- The Function Type 2 chain lost a substantial number of links during the study compared to the other chains, while Function Type 1 lost only one link.
- In general, the lighter the chain, the less fuel consumed and the lower the fuel cost.

Organisations supporting this research

This project was supported by LV Dohnt Logging Contractors, Southern Haulage Industries (SHI), Gunns Forestry, Australian Bluegum Plantations (ABP), Plantation Pulpwood Terminals (PPT) and the CRC for Forestry.

More information

For more information:
Project scientist Rick Mitchell: *rmitchel@usc.edu.au*
Alliance Director Mark Brown - mbrown2@usc.edu.au
AFORA website - *www.usc.edu.au/research/research-partnerships/australian-forest-operations-research-alliance/*