HARVESTING TECHNICAL NOTE

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A first look at the TR300 Remote Controlled Felling Wedge

Summary

Forest Growers Research has had a project underway for some years to develop or adopt a remote controlled tree felling wedge to make manual tree felling safer. The idea is that the tree faller cuts a slightly wider back cut in the tree, inserts the felling wedge, and then moves away from the hazard zone under the tree before using the remote control to tip the tree over. Various options have been designed, built and tested. The third version of a remote controlled felling wedge to be trialled, called the TR300, has been designed and built by Forstreich Maschinenbau of Germany. This wedge was made available to FGR for field trials, which are currently underway. This report focusses on the results of initial trials with the TR300 remote felling wedge to test its applicability to the New Zealand forest industry.

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INTRODUCTION

Using a felling wedge, or several wedges, to fell trees against their natural lean used to be common practice in motor-manual tree felling operations. With the increasing demand for mechanisation in New Zealand tree harvesting, the number of crews felling trees with chainsaws is significantly lower than it was ten years ago. Despite this, motor-manual felling is still common practice in at least 20% of ground-based operations and 60% of cable harvesting operations (Visser, 2019).

According to the FGR benchmarking database, where harvest areas are rated subjectively by forestry company personnel in terms of their harvesting difficulty, almost one-quarter of all operations in 2018 were rated as “hard”. The main reasons given included; “wind-throw salvage, the need to back-pull trees, and working around obstacles such as waterways, public roads, neighbours and power lines” (Visser, 2019).

While health and safety incidents involving the use of wedges have not been high statistically, the procedure to fell trees using wedges is still considered a high-risk task. Forest industry incident reporting indicates a significant risk factor is objects falling from above as the tree is falling. The closer a faller is to the tree as it starts to move, the higher the chance of an injury from falling objects that are dislodged during felling. In 2013, FGR initiated a project to develop easy to use tree felling wedges to improve directional felling, reduce tree breakage and improve faller safety (Vincent 2013; Vincent, Jackson & Beckham 2014; Vincent 2015). While these trials focused on improving directional felling and reducing the effort required to wedge trees over, they did not address the fact that the faller still needed to be at the base of the tree, directly beneath any object that might fall into that zone (Figure 1).

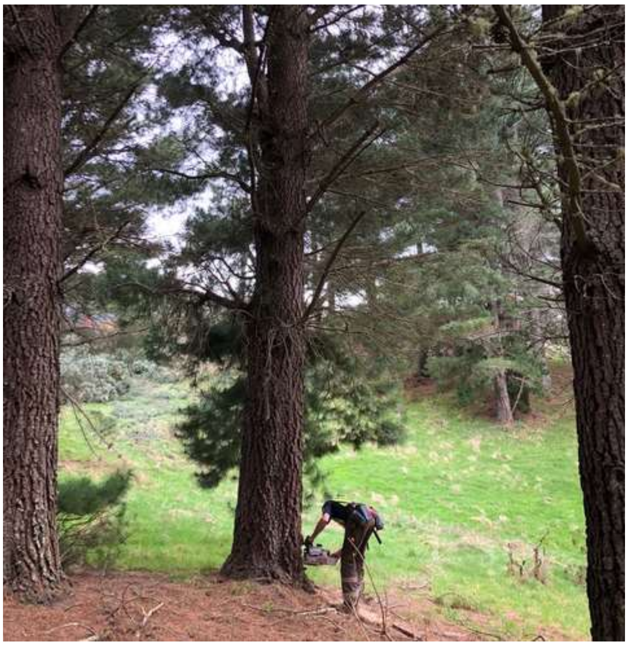

Figure 1: Manual tree felling involves risks associated with falling objects from above, as the tree begins to fall

The project, designed to replace existing felling wedges with a battery powered remote controlled wedge, arose from concerns the industry had about the number of manual tree fallers still required in harvesting operations on steep terrain, and the fact that there was little research aimed at improving the safety of these workers.

The earlier versions of the felling wedges trialled were manually-powered ratchet types, including the Hydrawedge (Vincent 2013); the Jackson Beckham mechanical felling wedge (Vincent, Jackson & Beckham 2014); and the Koller Mechanical Tree Feller (Vincent 2015). A remote controlled felling wedge designed and built by Applied Teleoperation Ltd in Rotorua was also trialled in the early stages of the project.

Issues identified with the earlier felling wedges trialled were:

- the weight of the wedge (often over 15kg);
- the time taken to manually insert the wedge (more than 90 seconds); and
- the limited stroke and lifting height, (these wedges tended to run out of stroke before the tree started to move).

The main disadvantage with the manually operated wedges was that they did not make the process of manual wedging any safer. Alternative methods of driving the wedge into the tree were investigated, including: using the chainsaw as a power source; pneumatic systems; hydraulic systems; and a system using carbon dioxide cartridges; but few ideas progressed to prototype stage.

Despite the operational issues in the trials with the manual-powered ratchet versions, the concept of forcing a tapered plastic wedge between two lifting plates had proven effective. Several models of wedge using this concept had become commercially successful, such as the Koller Mechanical Tree Feller (Vincent 2015) and the Forstreich TR30 mechanical felling wedge as shown in Figure 2 (Forstreich 2020).

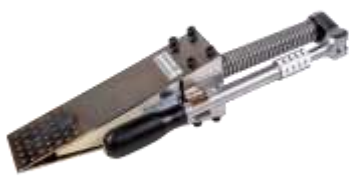

Figure 2: TR30 Mechanical Felling Wedge first launched at Interforst 2014 trade show

In 2018, FGR trialled a prototype battery powered, remote controlled felling wedge developed by Georg Miggitsch, ex-Service Engineering Manager at Koller Forsttechnik in Austria. While the initial concept showed promise, the first prototype wedge did not perform to expectations. It was heavy, (over 16kg), cumbersome to carry around, and did not have sufficient lifting capacity to tip over even relatively small trees against their natural lean.

In 2019, FGR received for trial, the recently released Fernbedienbarer Fällkeil TR300 (remote controlled felling wedge TR300), manufactured by Forstreich Maschinenbau of Freiburg, Germany (Figure 3).

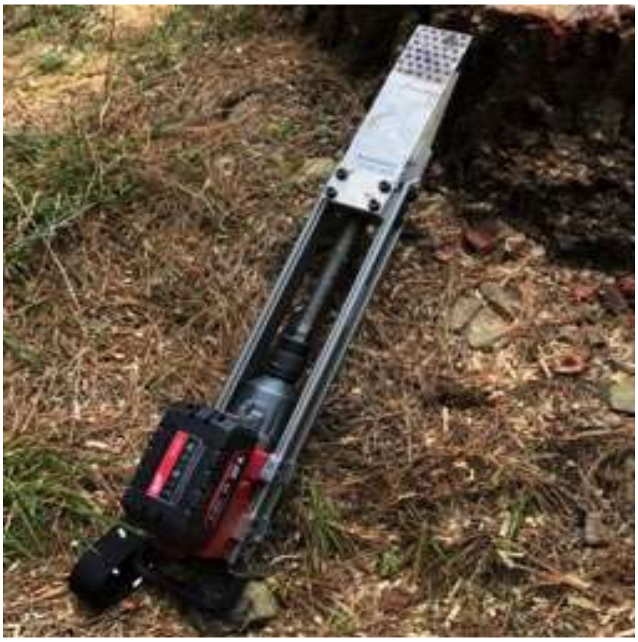

Figure 3: The TR300 Remote Controlled Felling Wedge

THE TR300 FELLING WEDGE

Forstreich Maschinenbau supplied the TR300 to FGR free of charge on the understanding that, if it worked effectively on the basis of initial trials, FGR would purchase it and promote its use in the New Zealand market. It was decided to follow the same testing procedure as laid out in the initial work plan prepared for the original trials with the Miggitsch wedge.

Specifications

The TR300 wedge is powered by a Milwaukee Li-ion battery unit and was supplied with a Milwaukee battery charger, a spare impact coupling, a spare plastic wedge and a replacement remote control antenna.

Unit price for the TR300 in Germany was €2800 (approx. 5000NZD), excluding batteries and freight. Given the high cost of Milwaukee batteries, a single 12.0Ah battery was purchased for the initial testing of the TR300. The larger

12.0Ah battery increased the operating weight of the wedge to 10.7kg. Specifications are given in Table 1.

Table 1: TR300 specifications

Item	Specification
Length	80 cm
Width	13 cm
Height	15 cm
Power	Li-ion battery
Weight (without battery)	9.2 kg
Weight (with 5.0Ah battery)	10.2 kg
Weight (with 12.0Ah battery	10.7 kg
Lifting force	25 tonnes
Lifting height	60 mm
Range of remote control	50 m

Operating Procedure

A threaded shaft, connected to the motor unit via an impact coupling, rotates clockwise through a bulkhead, forcing the plastic wedge out between the two lifting plates (attached to the bulkhead). As it turns, the shaft draws the motor unit along the two side rails towards the bulkhead.

A torque arm and sensors have been integrated into the unit, which automatically recognises the front and rear end positions of the wedge. When the shaft reaches the end of its thread, the TR300 automatically stops. At this point, it will have provided approximately 50mm of lift to the back cut of the tree being felled. To retract the wedge, the shaft is rotated anticlockwise. The motor stops when the wedge is fully retracted.

When there is no resistance, the speed of the TR300 to extend and retract the plastic wedge between the plates is relatively quick. The motor sounds like an ordinary electric drill when it is activated without load.

As the load increases, the motor reverts to the power mode and the sound changes to a rattling ("rat-tat-tat"), very similar to the action of a hammer drill when it encounters resistance. Under these conditions, the speed of the shaft is much slower and obviously a lot more powerful.

A simple battery powered remote control unit is used to activate the wedge and it has a range of approximately 50 metres. There is also a switch located on the back of the motor unit that can be used to control the TR300 functions when setting it in the tree.

According to instructions in the Operator's Manual, the TR300 should be inserted into a prepared slot in the back cut, no less than 7cm deep (this ensures all of the serrations on the lifting plates are buried into solid wood).

While no specific tree size was specified in the Operator's Manual, it was decided that the trials in New Zealand should target average second rotation pine trees between 1.5 to 3.0 tonne piece size.

On steep slopes or when the felling cuts are being put in from a height, the TR300 has a steel spike, (attached to the bulkhead by a nylon cord), that can be driven into the stump to stop the wedge from sliding down the slope or falling to the ground.

TRIAL SITE

The trial was undertaken in Rayonier Matariki Forests' Dalethorpe Forest in Canterbury, which was mostly P. radiata planted on converted farmland. Undergrowth in Dalethorpe was very light and the vigorous tree growth had resulted in a lot of relatively short, malformed trees, which appeared to have been damaged by snow. The terrain was gently rolling and some areas were lightly stocked with large gaps between small groves of trees. The piece size was considerably larger than one tonne, with the average diameter about 70cm and some very heavy branching, particularly on the malformed trees.

Conditions during both days of the trial were overcast with light rain on one of the afternoons. The general weather pattern during the trial was overcast with light winds in the morning that intensified as the day progressed.

Harvesting Crew Details

At the time of the trial only one contractor was motor-manual felling in Dalethorpe Forest. Renner Logging Ltd is a mechanised ground based operation based in Rangiora. They have the following machinery:

- Tigercat feller buncher
- Tigercat skidder
- Cat 527 tracked skidder.
- Tigercat / Southstar grapple processor
- Cat excavator loader.
- Sumitomo excavator loader.

Peter Renner, the prime contractor did most of the manual felling along with whatever tracking was required. The Cat 527 tracked skidder was

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mainly used for tracking and occasionally for extraction in difficult areas.

Scott Renner operated the Tigercat skidder and with Peter they are part of a crew of seven workers. Most of the manual felling done was around the fringes of the gaps because these trees tended to be larger and generally required some manual delimbing to enable them to go through the processor.

FIRST TRIAL

The initial trial was done in early October 2019, with contractor Peter Renner doing the falling and FGR project leader Rob Prebble operating the TR300 wedge. The purpose of this first trial was to make sure the TR300 was going to work in typical manual tree felling operations, and (subject to a successful outcome), to identify parameters that should be recorded in a more detailed, second trial.

The felling technique was to scarf and quarter cut the tree, then manually drive in a standard plastic wedge before the second stage of the back cut was made. A tapered slot was cut into this second back cut to enable the TR300 to be inserted so that all the serrations on the lifting plates were buried in solid wood. Both workers moved clear before the wedge was activated.

Results – Trial 1

Of a total of 13 trees, 12 trees were successfully felled with the TR300 wedge during the first trial (Table 2).

Table 2: Sample of trees felled with the wedge

Tree Number:	Diameter at stump (cm)	Tree Height (m)	Range (m from tree)
1	66	N/R	5
2	85	25.5	5
3	78	25.5	4
4	74	27.0	4
5	70	27.5	17
6	56	N/R	N/R
7	67	28.0	N/R
8	61	32.0	2
9	62	27.0	3
10	55	26.0	8
11	76	27.0	N/R
12	59	22.5	4
13	89	N/R	1
Average	**69**	**26.8**	**5.3m**

Attempts to fell the 13th tree were not successful because the battery ran out of charge, and the tree was felled with machine assistance from the Cat 527 tracked skidder. Table 2 shows the diameter and height of the trees felled and the distance away from the trees that the wedge was activated (range).

On two heavy back leaning trees, the TR300 ran out of lift before the tree tipped over, so stacked wedges had to be inserted to hold the tree in position while the TR300 was repositioned. This worked quite effectively and could be considered normal practice if a tree had a heavy back lean.

On tree number 6, the TR300 spat itself out of the back cut when it was activated. Prior to this, the barbs on the plates of the wedge had held it in the trees without a problem. This occurred a couple of times before it was realised that the TR300's plastic wedge had hit against a lip in the slot as it was being powered out and that was what pushed it out of the back cut (Figure 4).

Figure 4: The lip in the slot that pushed the TR300 out of the back cut

There was minor damage to the TR300's plastic wedge where it hit the lip in the slot but not enough to stop it being used (Figure 5).

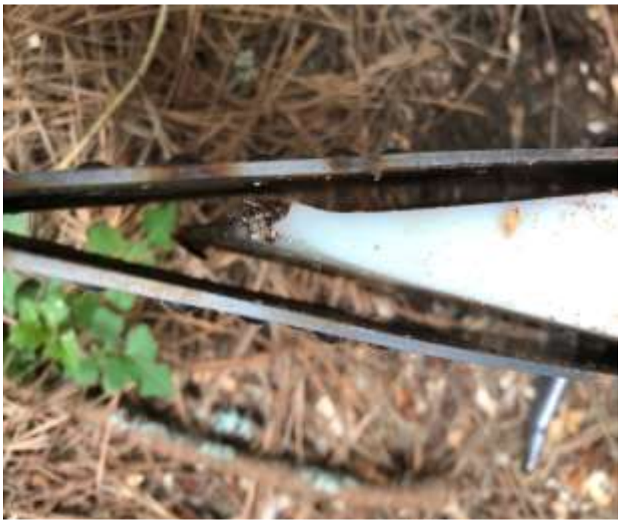

Figure 5: Minor damage to the TR300 wedge

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Once the slot was cleaned out and the wedge re-inserted, the tree tipped over without a problem. The learning from this incident was to make sure all cuts where the wedge was being inserted were clean and unobstructed.

On tree 8, the wedge was inadvertently inserted into a slot that had a bark pocket running through the centre of it (Figure 6).

Figure 6: Photo of the bark pocket that affected the lifting capability of the TR300

When the wedge was activated, instead of lifting the tree, it compressed the wood fibres around it and couldn't provide enough lift to tip the tree over.

Once it was discovered what had happened, the slot was cut deeper, but that didn't make any difference. The wedge was then repositioned to another position in the back cut to enable it to successfully tip the tree over.

A good learning from this incident was to check the tree carefully before selecting the location for the powered wedge slot. While bark pockets like this are hard to detect from the outside of the tree, indentations in the bark can be an indicator. Fortunately the plastic wedge inserted in the first part of the quarter cut held the tree up while the TR300 was being repositioned.

The average distance away from the tree from which the TR300 could be activated was 5.3m. On one occasion, it was successfully activated at 17m from the tree. The recommended distance is a trade-off between the faller being in a safe position and being able to see what is happening as the TR300 is activated.

On the 13th tree, the TR300 was about 85% extended when the battery went flat (Figure 7). The tree could not be lifted any further with stacked plastic wedges, and the TR300's plastic wedge could not be retracted, so the Cat 527 had to be used to push the tree over.

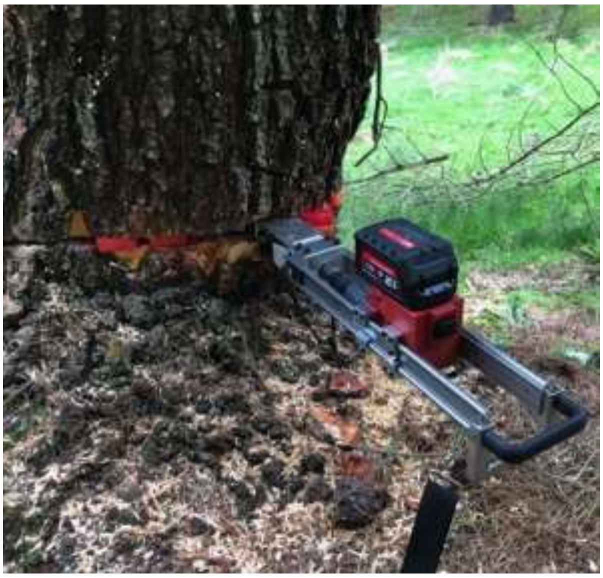

Figure 7: The battery ran flat with the TR300 almost fully extended

The lesson from this incident was that a back-up battery was essential if the powered wedge was being used for a full day. A second battery has since been purchased.

At one stage, contractor Peter Renner carried all of the equipment, including chainsaw and fuel containers to another patch of trees about 80m away without too much difficulty. The TR300 is nicely balanced and comes with a shoulder strap that makes it relatively easy to carry (Figure 8).

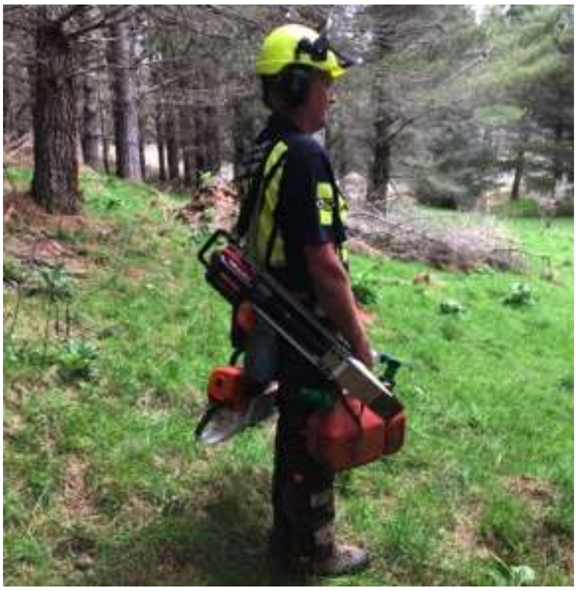

Figure 8: The TR300 along with all of the other felling equipment could be carried by one person

While Peter felt that it wouldn't be impossible for one person to carry the wedge around and use it on their own, it was definitely easier with two people. In his view, a faller wouldn't necessarily carry the TR300 on the off chance that it may be needed for one or two trees, but if it was a planned event and there was a number of back leaning trees that machines could not access, the TR300 would be used in lieu of a machine.

SECOND TRIAL

The second trial was designed to collect data on the time and energy required to use the TR300 wedge and compare it with using manual wedging techniques. A secondary objective was to quantify any operating boundaries around the use of the powered wedge.

In this trial contractor Peter Renner did the felling and operated the wedge while the author recorded times and took measurements. The parameters recorded were:

- The time taken to perform the various elements of the tree felling cycle.
- The dimensions of the trees felled and an indication of the lean of each tree.
- The heart rate of the faller when performing the various elements in the felling cycle.
- The distance away from the tree that the remote control could be used.

A stopwatch was used to collect element times, measured in seconds. Tree diameters and lengths were recorded using a small tape and a range finder and the clinometer function on a cell phone was used to measure tree lean, in degrees from vertical.

A Go-Pro camera was fitted to the faller's helmet and used in conjunction with a heart-rate monitor to record the effort required when performing the various tasks.

Results – Trial 2

A total of 30 trees were felled during the second trial, 13 of which were felled with the TR300, 16 required manual wedging and one was felled without any felling aids. The tree that felled without assistance is not included in this analysis.

Results of the trial are detailed in Table 3, which shows the element times and tree characteristics for felling trees using manual wedging and using the TR300 remote controlled wedge.

It took an average of just over one minute longer to fell trees with the TR300 compared to using manual wedging techniques (that is 2 min 36 sec vs 1 min 33 sec).

Table 3: Element times and tree characteristics for trees felled by manual wedging and the TR300 wedge

Type of Wedge Used	**Manual Wedges**		**TR300 Wedge**	
Element Times	**Average**	**Range**	**Average**	**Range**
Preparation (sec)	10.5	0 – 23	23.0	0 – 47
Scarf (sec)	21.9	14 – 40	22.0	14 – 28
Wing cuts (sec)	1.9	0 – 12	2.8	0 – 9
1st Back cut (sec)	15.4	10 – 26	20.3	11 – 34
Insert wedge (sec)	13.1	8 – 20	14.0	0 – 32
2nd Back cut (sec)	16.8	11 – 25	13.5	0 – 20
Drive wedge (sec)	13.6	0 – 55	0	-
Make slot (sec)	0	-	11.5	8 – 14
Insert TR300 (sec)	0	-	19.5	10 – 66
Activate TR300 (sec)	0	-	25.9	10 – 58
Total Delay-free (sec)	93.3	70 – 133	152.5	105 – 211
Delay (sec)	0.0	0	3.8	0 – 50
Total time (sec)	93.3	70 – 133	156.3	105 – 211
Other Measurements	**Average**	**Range**	**Average**	**Range**
No. of wedges used	1.6	1– 2	1.0	1 – 1
Tree lean (º)	-0.9º	0º to -2º	-1.3	1º to -4º
Tree Diameter (cm)	53.9	40 – 62 cm	51.3	31 - 60cm
Tree Length (m)	27.5	18 – 33 m	25.0	18 – 30.5m

Note that the time study was not contiguous as there was frequent discussion during the trial about whether or not the TR300 would be needed. Therefore the walk and select time, and a proportion of preparation time was not always recorded.

The relatively low quality of the trees meant that wing cuts were not common practice in this operation, hence the low average element time for wing cutting. Only 30% of the trees felled were wing cut and the average time taken to insert them was 7.5 seconds per occurrence.

Seven of the trees that were manually wedged fell as the second back cut was being inserted, which reduced the average time taken to drive the wedge in. While results showed it took only 13.6 seconds to drive the wedges in, the actual time per occurrence was 24 seconds. The faller used an average of 1.6 wedges per tree when manually wedging.

Every tree that was felled with the TR300 had a wedge inserted in the first part of the back cut. Results showed very similar times for inserting the wedge in the first part of the back cut between the two wedging techniques (13.1s for manual vs. 14.0s for the TR300).

Other elements in the felling cycle were relatively similar: inserting the first back cut took 5 seconds longer when using the TR300, but putting the second back cut in was 3.5 seconds slower when using manual wedging.

Obviously making the slot, inserting the TR300 and activating it, were elements that were not required when manual wedging. These three functions added 57 seconds to the TR300 felling cycle. The “Activate TR300” element included retreating to a safe position. The distance that the faller walked each time before activating the wedge was not recorded due to the dynamic nature of the felling operation.

There was only one delay recorded during the study and that was a 50 second delay related to using the TR300. It appeared that the battery had run flat as tree number 15 was being felled. This was an unexplained fault that seemed to correct itself with further use. The battery was removed and re-attached and the fault was corrected. The instruction manual states that the TR300 system will shut down after 4 hours without use, but that wasn’t the reason on this occasion, the TR300 had been used on tree number 10, only 9 minutes earlier.

The average back lean of trees felled with the TR300 was 1.3º, which is greater than the 0.9º recorded when manually wedging. This was a deliberate decision made by the felling team, which in hindsight may have undermined the perceived benefits of the powered wedge. By deciding to only use the TR300 on leaning trees that needed it, meant that trees that were manually wedged were easier and therefore would have required less effort.

The intention to relate physical demand against wedging activity resulted in good video coverage of the felling processes, but insufficient data was collected to draw any meaningful conclusions. Anecdotally, the faller stated that his workload seemed greater with manual wedging compared to using the TR300. This appears to be evidenced by the average heart rate recordings, which were 118 beats per minute for manual wedging and 108 beats per minute when activating the remote controlled wedge.

CONCLUSIONS

In this initial trial, the TR300 remote controlled wedge worked much better than expected. It was able to lift trees that appeared to be considerably larger and heavier than its design capacity, and far in excess of the two previous remote controlled wedges trialled by FGR.

The first trial clearly showed that care must be taken to remove any obstructions in the slot that the plastic wedge extends into. It is also very important to ensure that there is enough room for the wedge to fully extend to gain maximum lift. If working in trees that have heavy fluting or bark pockets, another lesson learned was to make sure the TR300 is inserted into solid wood, otherwise it is likely to compress the bark fibres and not provide the lift that is needed.

On large trees, if the TR300 runs out of stroke, the faller can stack a couple of plastic wedges into the back cut once the TR300 is fully extended, then retract and reposition it deeper into the back cut or add some packing under the wedge to increase its lift. This was effective during the first trial and could be considered normal practice when dealing with heavy back leaning trees.

While the charge level can be read by taking the battery off the TR300 and turning it over, it is not easy to monitor charge levels during operation. Based on the experience with the first trial, it is strongly recommended that a second, back up battery be available on site when the TR300 is being used.

The distance away from the tree that the TR300 could be operated from, was not tested extensively. While it was successfully activated at 17 metres during the first trial, further experimentation is required to establish the range that the remote can be operated from, without jeopardising the faller's ability to see what is happening at the stump.

In the second trial, comparing manual wedging with the powered remote controlled wedge, it took just under a minute longer per tree to make the slot, insert the TR300, then move clear and activate it. This extra time would be considered insignificant when compared with the extra cost of getting a machine in to assist felling, or delays in waiting for the hauler to back pull trees.

The general consensus of the team undertaking the trials was that the TR300 provided real lift at the plates, possibly as much as 25 tonnes which is what was claimed in the specifications. Use of the TR300 should be carefully planned. A faller shouldn't carry it around on the off chance that it might be needed. In other words, the TR300 isn't a replacement for the minimum requirement of 4 wedges and a driving tool when felling trees over 20cm. It would however be a useful alternative to machine assisting or back pulling trees.

Peter Renner commented at the end of the second trial that there was no way the trees that were felled using the TR300 could have been felled with manually driven wedges and he was keen to see further work done. His recommendation was that future trials should clearly identify the cross-over point where manual wedging becomes impractical and use of the TR300 is a viable alternative.

NEXT STEPS

- Carry out further trials to determine operating limits and develop recommended operating procedures, in New Zealand conditions.
- Provide an English version of the Operating Manual to assist training New Zealand loggers in the safe and correct use of the remote controlled felling wedge. (Note: This is now available).
- Establish a New Zealand-based agent for sales, marketing and after-sales service and support. This will be an important step in establishing widespread availability and use of remote controlled felling wedges in New Zealand harvesting operations.

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