PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email: info@ffr.co.nz
Web: www.ffr.co.nz

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Development of an Improved Felling Wedge for Directional Felling - Initial Trials

Author:
B Vincent

Research Provider:
Tramroad Limited

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INTRODUCTION

Brett Vincent of Tramroad Limited was assigned to complete trial objectives to establish whether the concept of a hydraulic tree felling wedge (Hydrawedge) can improve the accuracy of directional felling and reduce breakage, to improve cable extraction productivity and increase harvesting value recovery.

This report documents the trials undertaken, summarises the issues identified with the hydraulic tree felling wedge, and provides “proof of concept” for the Hydrawedge. The report also provides project direction for further development of a productive, lightweight, usable and powerful felling assistance device.

BACKGROUND

A hydraulic tree felling wedge called the “Hydrawedge” (Figure 1) was purchased from the United States in 2012 for evaluation and, if necessary, further modification. The Hydrawedge was to be used in cable harvesting operations to determine if it could successfully achieve the following objectives set out in the work plan.:

- to improve the accuracy of directional felling;
- to reduce felling breakage and thus enhance productivity and value recovery;
- to eliminate tree driving and the hazard of driving-related accidents and deaths; and
- to provide project direction to steer the further development of a productive, lightweight powered felling wedge.

Brett Vincent of Tramroad Limited worked with a number of tree fallers in trialling different techniques to ascertain “proof of concept” for the Hydrawedge. A lot of discussions were had with the tree fallers about the concept, use and accuracy of the felling wedge, and their ability to work with it. Ideas were discussed with logging contractors and other forest industry people in order to improve the current prototype. The consensus was that a lighter, more user friendly felling wedge needs to be created. The next prototype must be safe to use, have user acceptance and provide accurate tree felling with less breakage.

Figure 1: The Hydrawedge successfully wedging a tree over

TRIAL PROCESS

The trial process was designed to replace the use of existing felling wedges with the use of the Hydrawedge. The Hydrawedge trial was to prove the concept that a felling assistance device can improve directional felling and therefore decrease breakage and increase production. A secondary objective was to determine the direction FFR will take in the development of the second prototype felling wedge.

The Hydrawedge comprised a wedge 150mm long and 25mm high, and a hydraulic jacking ram to push the wedge through two plates inserted into the back cut of the tree.

During the trial the tree faller had control of the felling site, the tree felling process and the use of the Hydrawedge, and used an assistant to carry the Hydrawedge and make observations. If the tree faller considered that the Hydrawedge should not be used because of safety concerns or production issues, then the assistant moved aside until it was safe enough or we had the time to continue with the trial work.

Trial: Day One

The first contractor trialled using the Hydrawedge was Stubbs Contracting Ltd, a cable harvesting and ground based contractor from Gisborne. Robert Stubbs, the principal contractor, had some edge trees to fall.

Arriving on the job site the first observations from the skid site suggested that the piece size of the block was 4 tonnes average. The process required to fall the edge trees was discussed with the foreman. He suggested that we move to an area of edge trees where a machine could help the tree faller if we had any difficulties.

The piece size of the first tree chosen was close to 10 tonnes weight. The scarf and first quarter cut were placed in with a faller's wedge to hold the tree. The second quarter cut was placed in and the Hydrawedge inserted into the tree. The wedge ran out of stroke when only 75mm into the tree. The tree did not move at all, nor did it look like moving without some serious power behind it. The machine operator was instructed to push the tree over.

Figure 2: Two tree fallers from Stubbs Contracting Ltd

Four others trees were tried and the Hydrawedge failed to wedge any of them over. One question was whether the technique in using the Hydrawedge had effectively failed.

The principal contractor provided two other experienced tree fallers to work with the wedge for a further three hours to allow further examination of the reasons for the initial failures with the large edge trees (Figure 2). Different techniques were used to make the Hydrawedge more effective.

Faults and Issues Arising from Day One

Assessing the human and mechanical faults the issues that the Hydrawedge had presented whilst completing the first trial day were:

1. Failure to fully insert the Hydrawedge into the back cut. The back cut closed tight on a couple of occasions, therefore insertion was impossible. To counteract this, an existing wedge was used to hold the back cut open to insert the Hydrawedge. The back cut height itself halted full insertion. With this knowledge, a thin wedge was cut in the back to insert the Hydrawedge fully before pumping the Hydrawedge into the tree (Figure 3).
2. Weight of the tree. The weight of the tree would crush the wedge of the Hydrawedge. Once the Hydrawedge was inserted fully the fresh cut wood fibres would crush around the wedge, eliminating any effect of the wedge's ability to tip the tree over (Figure 4).
3. Stroke length. Numerous times the stroke ended before the tree even moved. Conventional wedges had to be inserted to increase the opening of the back cut. This enabled full insertion of the Hydrawedge to make use of the entire stroke of the Hydrawedge.
4. Operator mind set. Going into the initial trial day the consensus was that the Hydrawedge was a jacking device to tip edge trees over. This concept proved to be wrong very quickly. And even with trees within the stand the Hydrawedge struggled with the bigger wood.

Figure 3: Tree faller from Stubbs Contracting Ltd inserting wedge

Figure 4: Attempt to increase the wedge height

Trial: Day Two

It was agreed to do another day's trial with the Hydrawedge, this time in a harvest block of more normal piece size (two tonnes average). The trial was undertaken with Rodney Hubbard of H&R Harvesting Ltd's roadlining operation in Rotorua.

The tree faller set about felling trees using the Hydrawedge. The stand was leaning opposite to the extraction direction. With the more manageable 2-tonne tree size, the faller continued to successfully use the Hydrawedge all day to fell trees side by side (Figure 5).

Each tree had a little slot cut out of the back of the tree to insert the Hydrawedge as far as possible. Using the full stroke of the Hydrawedge, the trees tipped over with ease. As a result of the success of the second day of trials, the decision was made to make an initial low cost modification to the Hydrawedge.

Figure 5: Wood laid side by side at H&R Harvesting Ltd

New Additions

The additions to the Hydrawedge were to add extra height and increase the stroke length to the existing wedge (Figure 6).

A local engineering company was contracted to make changes to the Hydrawedge. Three holes were drilled into the existing wedge and another steel wedge was screwed to it. The new wedge lengthened the stroke from 150mm to 250mm. It also increased the wedge height to 50mm. One of the outside slide plates was turned to allow for the extra wedge height.

Figure 6: Hydrawedge with the additional black wedge added

Trial: Day Three

After the additions had been made, another day's trial was arranged with the H&R Harvesting Ltd's roadlining operation in Rotorua. The aim of the third day was to confirm the additions to the Hydrawedge. The following questions had to be answered: Would the wedge push itself out of the back cut? Could the wedge be inserted into the tree? Was the Hydrawedge powerful enough to jack the tree over?

The Hydrawedge worked incredibly well; the stroke length was sufficient to jack every tree over with ease. Occasionally the entire length of stroke was used.

With the increase in wedge height, a new issue had arisen – the Hydrawedge wanted to push itself out of the back cut when inserted against bark. The bark would peel away from the tree and jack the Hydrawedge out (Figure 7).

In the afternoon work session, the wedge was trialled with edge trees. Realising the limitations of the Hydrawedge from past experience, trees within the capability of the Hydrawedge were selected. On a couple of occasions the end of the stroke was reached before the trees tipped over.

From the testing of the new additions at H&R Harvesting, a further two-day working trial back at Stubbs Contracting Ltd, Gisborne was arranged.

Figure 7: Hydrawedge pushing itself out from the backcut

Figure 9: Bark cleaned and slot opened in the backcut for full Hydrawedge insertion

Figure 8: Hydrawedge not fully inserted and coming to the end of its stroke

Trial Day Four: Cable Harvesting Settings

On the first day back at Stubbs Contracting Limited the Hydrawedge was used with one of the previous tree fallers, finishing off a hauler setting that had been started earlier that week (Figure 10). The piece size on the hauler setting was around 2.2 tonnes. The setting was completed positioning the trees successfully where they were required to fall. The Hydrawedge was not used to fell every tree.

Figure 10: Stubbs Contracting Ltd hauler setting

Weight of Wedge

The original weight of the Hydrawedge before additions had been made was 10 kg. The additions to the Hydrawedge had increased its weight to about 15 kg, which is quite a heavy weight to carry around on steep terrain. In practical terms this becomes a two man job, one to carry and operate the Hydrawedge and one to complete the felling using the chainsaw.

With the extra weight two hands were required to carry the Hydrawedge. This created difficulties as a person's arms and hands are often required to reach out and balance when walking around the forest, especially over scrub and undergrowth.

Using the Hydrawedge in the hauler settings required the fallers to be very careful of their footing. The assistant slipped on some occasions whilst carrying the Hydrawedge.

Figure 11: Stubbs Contracting Ltd hauler setting trial work

Large Edge Trees

Later that afternoon, the Hydrawedge was used to fell some large ground-based edge trees (Figure 12). The average piece size in this felling site was 4 tonnes with some trees over 80cm diameter.

The tree faller set about felling the first tree using conventional cuts and three 250mm wedges.

After felling the first tree the faller and assistant then reassessed how the subsequent trees would be fallen. On the next tree, a large 250mm wedge was inserted to hold the back cut open before inserting the second quarter cut.

Figure 12: Stubbs Contracting Ltd large ground based trees

For subsequent trees the felling process was modified to use the Hydrawedge in place of the 250mm wedges to hold the back cut open. We had to cut a large slot to allow the Hydrawedge to be fully inserted before inserting the second quarter cut.

Twelve further large edge trees were felled. The wedge, with the additions made, proved that large edge trees can be successfully felled. A couple of times the wedge ran out of stroke, which was overcome by inserting the large 250mm wedges and reinserting the Hydrawedge into the tree further.

Figure 13: Shows height of backcut and size of trees

The following day a ground-based setting within the stand was opened up. The first ten trees were felled without using the Hydrawedge to open up a hole. After the difficulties of the previous day felling the edge trees, the objective was to find techniques to reduce the work load.

The first alteration to the conventional method was that the depth of the scarf face was increased to nearly half. It was more effective if the core in the scarf was seen.

The next change was that the height of the back cut was increased to nearly double the normal height. These changes allowed the wedge to be inserted and with not much effort the tree was moved past the centre of balance. A slot was still inserted in the back cut and the bark layer cut away to overcome the earlier issues. The changes also allowed less weight to be lifted before the tree's own weight moved it to fall (Figure 13 and 14).

The methods used to operate the Hydrawedge effectively were outside the guidelines of the Approved Code of Practice for Safety and Health in Forest Operations. The tree felling was safe in the controlled environment of the setting that had been created, and the two tree fallers were experienced and had good tree felling skills. In a production situation however, allowing fallers to over-cut the tree's scarf and increase the height of the back cut could result in fallers being put into serious harm situations, which is obviously not acceptable.

Figure 14: Shows height of backcut and depth of scarf

PROOF OF CONCEPT

Proving the concept of using another device for felling assistance required the following questions to be answered. Did the use of the Hydrawedge felling wedge:

1. Improve the accuracy of directional felling?
2. Reduce felling breakage and thus enhance productivity and value recovery?
3. Eliminate tree driving and the hazard of driving-related accidents and fatalities?
4. Provide direction for further development of a productive, lightweight powerful felling wedge?

These initial trials showed that the Hydrawedge did improve the accuracy of directional felling of trees. Although not measured, the observed flow-on effect was that directional-felled wood reduced breakage as trees were laid side by side and not crossed over.

Reduced felling breakage led to fewer pieces to pick up and therefore improved extraction productivity.

Use of the Hydrawedge eliminated the need to drive trees because it had the power to wedge trees over individually. During the trials the Hydrawedge was also used to fell some dead spars. The faller inserted the scarf and back cut and the Hydrawedge was inserted and pumped the spar over. The Hydrawedge improved the safety of removing the hazardous spars by:

- allowing the operator to watch the top of the spar at all times, keeping focus on the spar instead of hitting the wedges;
- quiet operation, allowing operators to listen out for falling debris from the top of the spar; and
- eliminating hitting and jarring the spar, causing breakage.

The same safety benefits apply to felling green standing trees.

The trials of the Hydrawedge allowed tree fallers to gain insight to provide project direction to steer the further development of a more productive, lightweight powerful felling wedge.

Further trials need to answer four questions.

1. Does the accurate tree placement enhance breakout element time and thus hauler productivity?
2. Does accurate tree placement minimise tree breakage during felling?
3. Does accurate tree felling minimise tree breakage at breakout?
4. Does wedging each tree have safety benefits for the faller?

DESIGN ISSUES TO BE ADDRESSED

The Hydrawedge design had a number of issues that became apparent as it was used in these initial trials:

1. **Weight of the current wedge**. The impracticality of the Hydrawedge design would result in a faller not wanting to carry it around and use it. The addition of the extra wedge resulted in the unit weighing close to 15 kg.
2. **Inserting the Hydrawedge into the back cut.** The two plates that cover the wedges became bent and buckled making it hard to insert. Insertion proved difficult from a conventional chainsaw chain cut width. The faller cut a little wedge so the insertion became effective. The outside plates would also catch on the bark. (Figure 15). When the wedges were pumped into the tree the bark would peel off due to the pull from the outside plates. The faller would have to slice the bark away from the tree before the wedge could be inserted. Quarter cuts and split level cuts were used to insert the wedge before the tree sat back. Once a tree sat back it was impossible to insert the wedge. Conventional wedges had to be used or a driver tree used to drive the tree down.

Figure 15: Hydrawedge pushing itself out of the backcut

3. **Longer stroke.** Numerous times the Hydrawedge ran out of stroke and a conventional wedge had to be used to hold the tree while the Hydrawedge was reinserted deeper into the cut. It was a big issue with the current Hydrawedge set up, but with the additions the stroke issue was less common.
4. **Speed of Operation.** Pumping the Hydrawedge wedge into the tree took about 90 seconds. Faster movement causes different reactions to the tree and therefore less exertion. Hitting conventional wedges into a tree commonly takes from 20 to 90 seconds
5. **Visibility.** The outside plates for the Hydrawedge didn't allow the user to determine the location of the wedge as it was being inserted. The faller had to always look to the side to check the wedge's location within the back of the tree, while still pumping the handles.

Ideas for Improvement

To meet the objectives of the trial, the next design needs to:

1. Be light weight. A faller has to carry this item on their work belt.
2. Provide quick insertion. The faller needs to insert the felling assistance device into the back cut quickly and safely. No additional cuts should be needed to account for the new felling assistance device.
3. Have a long stroke. The faller must have enough movement with the felling assistance device to tip the tree over in one go. This may entail either pushing on a vertical or horizontal axis.
4. Move faster. The faller wants to get the tree over as fast and safely as practicable.
5. Provide visibility. The wedge must allow the faller to know what is happening with the device at all times from an operating position.
6. Be easy to use. For acceptance by fallers the wedge must be effective in completing the task.

Options Considered

A number of ideas for the further development of a more productive, lightweight powerful felling wedge have been considered, discussed and processed, including:

1. A pneumatic air bag the thickness of a back cut, so it can be inserted into the tree. The air hose would be connected to the exhaust of the chainsaw. The air bag is pumped up and the tree falls over.
2. A hydraulic pump. Connected by a hose to the sprocket of the chainsaw. The pump would be connected to a thin ram placed into the tree. The ram is then pumped up and the tree falls over.
3. Creating a lighter version of the current Hydrawedge.
4. Creating a powerful impact hammer for better wedge control.

Options are available from around the world to use as a felling assistance device. These options need to be modified to suit our situation. One example is the Fire Department using air bags to lift cars off people using a gas cylinder requiring only low PSI.

Recommendation

One option is to pass this project on to Canterbury University forest engineering or mechanical engineering to redesign the Hydrawedge. FFR resources can be provided to assist the students to generate ideas for the next prototype.

A timeframe of at least 3 months would be required to provide a workable solution. Each of the options above may require about $10,000 materials costs, plus student time and resources required.

FFR can also help in organising trial work of the next prototype. Further development work can be done in the field as the prototypes are trialled.

CONCLUSION

It was clear that the felling assistance device needs to be workable for the tree faller. It is not acceptable to expect workers to use a heavy, slow hydraulic wedge such as the existing Hydrawedge and continue to be productive.

The initial trials have proved that the concept works. The concept that good directional felling reduces breakage was found to be correct. Giving a manual faller a tool to directionally fell trees all day long, eliminating the need to drive trees, will enhance the safety of manual tree felling and increase extraction productivity.

FFR should continue development of a safe lightweight, powerful felling assistance device. Four options to develop in the next prototype have been presented: a pneumatic ram or air bag; a hydraulic pump; a lighter version of the Hydrawedge; or a powerful felling hammer. Further development will require resources and some innovative thinking. Recommendations from these initial trials are to involve forest engineering or mechanical engineering students in this design process to solve the problems presented by the Hydrawedge design.