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Innovative Yarding Systems – A Review of Literature

Summary

Breaking out (attaching tree stems to cable rigging) is one of the most hazardous tasks in the forest industry, and is one of the tasks most commonly related to serious harm injuries and fatalities. A key area of focus for the FFR Innovative Harvesting Solutions programme is to isolate workers from these hazards by developing new harvesting systems using mechanisation, remote control and semi-automation.

One of the project objectives of this programme is to develop an innovative yarding system to improve the safety of steep country harvesting, and reduce harvesting costs on steep terrain by 30%. A number of ideas for such a system were generated by the New Zealand forest industry through a series of workshops. As part of this project a review of international literature was completed to identify any other ideas or developments, and to compare the locally-inspired innovations against international developments. The literature search used the following key words: *cable logging carriages; grapple carriages; mobile tail holds; mobile anchor; anchors; anchoring; automation in cable harvesting; automatic cable harvesting; automatic control; remote control; self-propelled carriages; drive mechanism for self-propelled carriage; capstan winches; dual capstan winches.* The literature search did not reveal any publications or patents that were similar to the innovative yarding system as proposed in this FFR project.

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INTRODUCTION

Steep-country harvesting using cable yarders is the lowest productivity, most hazardous and highest cost process in the forest industry. The industry has recognised that a cost reduction of 25% through improved productivity is needed in order for cable harvesting to be cost-competitive. Also, steep country harvesting jobs must be made safer. Harvesting steep country is hazardous for “breaker-outs”, the workers that attach the tree stems to cable rigging during extraction. Along with felling, breaking out is the task most commonly involved in serious harm and fatalities in the forest industry. Between 2005 and 2010, the Incident Reporting Information System (IRIS) managed by the Forest Owners Association recorded 18 fatalities in New Zealand. Tree felling and breaking out contributed to 39% of these fatalities [1]. A key area of focus for the FFR Innovative Harvesting Solutions programme is to develop new productive harvesting systems that eliminate the need for breaker outs and tree fallers [2].

Despite the availability of some New Zealand-built yarder models such as the Brightwater Yarder, Madill 124 swing yarder and the Harvestline, the New Zealand logging industry is still heavily reliant on ageing second-hand cable yarders imported from North America [3]. There is a need for the cable hauler machinery industry in New Zealand to grow substantially to future-proof the expansion of the industry in steep terrain harvesting.

A number of the European manufacturers have developed sophisticated radio-controlled semi-autonomous machines that have a high degree of in-built control, some of which can be transferred to this project to direct the grapple carriage to the next tree. However, European cable harvesting equipment commonly has lower power and line pull than the North American counterparts favoured by New Zealand loggers. While these machines may have a place in the New Zealand cable logging scene in the future, New Zealand cannot necessarily rely on importing European technology to solve all its harvesting challenges [4].

The objective of this project in the FFR Innovative Harvesting Solutions programme is to design an alternative new extraction or yarding system which can reduce extraction costs and achieve productivity gains of 30% over current steep country extraction systems. The aim is to develop the new system to alpha-prototype stage. The ultimate development of the FFR programme is an innovative yarding system that will produce a step change reduction in the cost of steep terrain harvesting. The Innovative Yarding System project began in 2012 with a series of brain-storming workshops where 45 harvesting management staff, contractors, consultants and

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researchers generated 72 ideas to improve the way cable harvesting is undertaken in New Zealand [5].

These ideas were shortlisted to eight innovative yarding systems, using an expert panel and broad level technical and economic feasibility, which compared the shortlisted concepts to more typical cable systems used in New Zealand in terms of productivity and cost[6]. Further analysis of engineering feasibility was then conducted, but the results showed that the concept was not going to meet the project goals. The expert panel reviewed the other potential ideas, but these were deemed to be either too difficult or too ambitious to be completed within the scope of this project.

At this stage a new concept was proposed by Awdon Technologies Ltd, a design and development company from Gisborne, New Zealand. As part of this project, a review of international literature was completed to identify other ideas and to compare the locally-inspired innovations with international developments. This report summarises this review of literature relevant to the Innovative Yarding System project.

METHOD

The following key words were used for the literature search:

- Cable logging carriages
- Grapple carriages
- Mobile tail holds
- Mobile anchor
- Anchors
- Anchoring
- Automation in cable harvesting
- Automatic cable harvesting
- Automatic control
- Remote control
- Self-propelled carriages
- Drive mechanism for self-propelled carriage
- Capstan winches
- Dual capstan winches

The design features of the innovative yarding system as proposed by Awdon Technologies Ltd were checked against previous developments identified in the international literature for evidence of innovation.

RESULTS

Grapple Carriages

Grapple carriage developments have a long history dating back to the 1960s. A number of variations of grapple carriages were designed and built at around that time. For example, Johnson Industries [7] began production of their mechanical logging grapples in the early 1960s. The design hasn't changed much over the years, and Johnson is still a major supplier of grapples suited to three-drum machines. Johnson grapples are typically used with interlocked swing yarders.

In 1977, Hale[8] developed a remote-controlled hydraulic grapple carriage powered electrically. The scissor-type grapple was attached to the bottom of the carriage at a turntable, which was rotated by a hydraulic motor from within the carriage. Mitchell [9], in 1972, designed a grapple carriage for operating on a skyline. The carriage worked in the same way that the modern Johnson grapple operates. A closing and opening line was necessary to open the scissor-style grapple. One of the first commercial grapple carriages was developed by Eagle Carriage and Machine Inc. [10] in 1977, and soon after the Eagle Mega Claw, a hydraulically operated grapple powered by a diesel engine was developed. The Eagle Claw did not sell well in New Zealand, possibly because the technology was ahead of its time. The carriage relied on a live skyline in a shotgun or a slackline rigging configuration. The carriage came with a camera system as well.

Maki developed a remote-controlled grapple carriage in 1997 [11]. It also was reliant on a live skyline like the Eagle claw, except that the grapple had some lateral movement. The design had a number of rotating parts to aid grapple positioning. Two units were sold into New Zealand operations, but this technology was not more widely adopted here, possibly because it also was ahead of its time.

In 2007, Torgerson [12] proposed a grapple carriage design with the advantages of being lightweight and having power-closing grapple arms. A lightweight design that could work in lower deflection settings was the key to enabling a larger area to be grapple harvested. Later in the same year, Baker[13] developed almost the same grapple carriage as Torgerson, but without the power-closing rams. Baker used the mainline to close the grapple working against the carriage being clamped to the skyline. A

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small engine was used to generate hydraulic pressure, which was stored in an accumulator. Over time, grapple carriages have been designed to be lighter to allow greater payload, and also to allow grapple harvesting to be carried out in areas of poor deflection.

In 2011, Dale Ewers, a Nelson logging contractor, developed the Falcon Forestry Claw [14]. The aim was to improve safety of operations and reduce the breaker-out's exposure to the many hazards of breaking out. The Falcon Claw has an engine powering a hydraulic system that provides plenty of force on the grapple tines (Figure 1).

Figure 1: Falcon Forestry Claw

The current model of the Falcon Forestry Claw weighs 2.1 tonnes and is well suited to larger tower haulers. A second, lighter model (weighing 1.4 tonnes) is currently under development for smaller towers.

In 2012, a South African manufacturer of grapple carriages (Alpine Logging Equipment) supplied a grapple carriage for New Zealand logging conditions as part of the FFR steep land harvesting development programme[15]. Alpine focussed on producing a light-weight grapple carriage (Figure 2) aimed at the types of small yarders and swing yarders that had difficulty running the normal mechanical grapples available on the market. The grapple arms of the Alpine grapple carriage are powered open with hydraulic rams using stored hydraulic pressure from an accumulator pressurised from a sheave-driven pump.

Figure 2: Alpine Grapple Carriage

Self-Propelled Grapple Carriages

Self-propelled carriages have been used in logging applications since 1964. Typically, the drive mechanisms have been of a capstan winch type arrangement as seen in the Konrad Woodliner and Fux SK2000 carriages in Europe [16], and the Skycarry and Radicarry carriages in Japan [17].

The drive mechanisms of these carriages can achieve carriage speeds of up to 4.8 m/s [16]. These carriages have primarily been used with standing skylines and for downhill extraction. No literature could be found combining self-propelled carriages incorporating a grapple working with a live skyline system. The Fux self-propelled carriage could work over an intermediate support given that the driving line was separate from the skyline.

In 1987, Kimblad [18] designed a self-propelled carriage. The drive mechanism was a wheel having spokes arranged in two rows forming a V-shape. The spoke arrangement enabled the drive wheel to engage with the cable. Wyssen carriages[19] are capable of travelling over lateral deflection of the skyline (Figure 3).

Innovative Yarding Systems

The review searched for literature on Innovative yarding systems incorporating grapple use. In 1983, MacMillan Bloedel modified a Madill 009 machine to enable grapple yarding [20]. The modification included splitting the main drum, providing a line shortener to

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account for variations in line length, adding a sheave at the top of the pole and changing the hauler controls. The modified Madill 009 worked well and this concept is still applicable today, possibly even more so.

Figure 3: Wyssen system for operating over deflected skylines. Source www.wyssen.com

Hirano in 1988 [21] developed an idea to try and solve problems, as he saw them, with (a) driving a self-propelled carriage to the back face of a setting; (b) overcoming slippage of the capstan type drive mechanism; and (c) the need to be able to brake the inhaul of the trees as they are pulled off the back face. His invention used multiple lines in multiple capstan type drive wheels. The whole invention appears difficult to set up, with a total of four cables required.

Bunching was first used in harvesting with feller bunchers on flat terrain. Early trials with grapple yarding bunched wood were done in the late 1980s [22,23]. In 2006, Wood Contracting (Nelson) Ltd introduced steep country bunching to New Zealand [24]. The steep slope system used by Ross Wood incorporated a dozer at the top of the hill connected to an excavator via the dozer winch. The excavator was then used to bunch trees and present them to the grapple for easy grapple loading. The winch rope from the dozer winch provided additional traction to the excavator when moving. The system increased production substantially over conventional grapple yarding systems.

A very similar system was implemented in Malaysia where Alpine Shovel Yarders were used to extract small piece size *Acacia mangium*. Using excavators to bunch and present tree bunches for the grapple carriage more than doubled the production of a more conventional extraction system using breaker-outs and manual slack-pulling carriages.

DISCUSSION

As part of this project Awdon Technologies Ltd proposed a concept innovative yarding system to FFR that involved three carriages and a yarder working in unison to grapple harvest. The concept has taken the best of the ideas previously developed through the project, along with some new ideas, to develop an innovative harvesting solution.

Various features of the FFR Innovative Yarding System as designed by Awdon Technologies Ltd have been used in previous developments. For example, the Awdon Technologies design has the grapple rotator inside the carriage as Hale had designed in 1977, as opposed to more recent designs such as the Falcon Forestry Claw and the Alpine Grapple Carriage where the rotator is external. Having the rotator in or out of the carriage is a choice made around protection of the rotator and available space inside the carriage, and does not limit the originality of the Awdon design.

Like the Falcon Forestry Claw, the Awdon grapple will be powered by an internal engine that will run the hydraulics. The Awdon grapple carriage will have a small bunching arm to allow the first tree in the grapple to be held while a second tree is grappled. This will be much the same as the bunching arm retrofitted to the Falcon Forestry Claw.

A number of features of the Awdon design are different from other grapples on the market. Compared to the Johnson grapples suited to three-drum machines, the Awdon design will operate the grapple with only two lines, the skyline and the mainline. A tail rope will not be required as the carriage will be self-propelled for outhaul. It will have sufficient drive to climb the skyline on the back face towards the tail hold. The drive mechanism proposed by Hirano is similar to that of the Fux SK2000 carriage, and therefore is very different from the drive mechanism of the Awdon grapple carriage.

The drive mechanism proposed by Awdon Technologies Ltd is innovative and appears to be the first time this type of drive will have been used. The Awdon concept will be intermediate support capable

as well as being capable of driving over a lateral deflection carriage. Wyssen carriages are capable of travelling over lateral deflection of the skyline, but the Awdon system will be more dynamic.

Apart from hydraulics and remote control the Awdon design does not include many of the features of the Eagle Claw. Likewise there is little in the Alpine grapple carriage that would be incorporated in the Awdon grapple design.

The proposed Awdon tail hold carriage will reduce the requirement for specialised tethered machines to fell, bunch and present trees to the grapple. Being able to shift the skyline sideways and have good line speeds on the outhaul phase of the cycle will mean that good production will be possible without the expense or environmental concerns of bunching machines operating on steep slopes.

During the innovative yarding workshops, six of the 72 (8%) ideas involved better systems for shifting the skyline. The Awdon design features an integrated backline-moving system. Very few new developments in this area were uncovered in the literature search, apart from the use of mobile tail holds commonly in use in cable operations for many years.

There have been no other innovations in a moving tail-hold winch system such as that proposed by Awdon Technologies. Also, no literature was found describing the use of rubber tyres to drive a logging carriage along a skyline.

CONCLUSION

A review of current international literature did not reveal any publications or patents that were similar to the innovative yarding system as proposed in this FFR project. The yarding system as designed by Awdon Technologies Ltd is therefore deemed to be innovative. Through the use of a grapple carriage to replace manual breaker-outs it will improve the safety of steep country harvesting. It also shows the potential to be highly productive and reduce line-shifting delays through the use of a tail hold shifting mechanism, thereby reducing harvesting costs on steep terrain. Work is continuing to develop the design of this innovative yarding system.

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