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Scorpion Grapple Carriage: Concept Appraisal

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1 EXECUTIVE SUMMARY

The specific aim of one Future Forests Research harvesting project is to increase the uptake by the New Zealand forest industry of grapple harvesting to improve safety and productivity. The critical factor of achieving satisfactory payload while grappling has been recognised as one of the barriers to increased adoption of grapple harvesting. The advent of new hydraulic grapple carriages such as the Falcon Forestry Claw and the Alpine Grapple has reinforced the need to improve payload and lateral yarding capability during grapple yarding in order to increase productivity.

This project was aimed at supporting the development of the Scorpion Grapple carriage, an innovative dual arm grapple designed to facilitate the extraction of two tree stems per cycle. This report documents the initial development of the alpha prototype Scorpion Grapple carriage by Scorpion Limited of Napier. Part of the project was to commission an independent consultant engineering report reviewing the engineering feasibility of the Scorpion Grapple design. Index Engineering Ltd of Rotorua was engaged to provide an engineering appraisal of the Scorpion Log Grapple Carriage concept.

Index Engineering Ltd made two site visits during construction, including discussions with the developers, Scorpion Limited of Napier. Aspects of the mechanical, hydraulic, electrical and electronic system were assessed, and a total of 26 recommendations were made.

According to Index Engineering Ltd, the overall concept appears sound, with several safety advantages compared to existing cable extraction systems. Advantages of the Scorpion grapple include the concept of harvesting a wider area at any one time, which is likely to lead to production efficiencies and cost savings.

At the current point of development however, Index Engineering Ltd is not yet satisfied that the Scorpion Grapple is technically feasible. Areas for focus in further development stages that need to be fully analysed and addressed have been identified. These relate to transportation of the Scorpion and assembly on site, centre of gravity considerations, battery life, and operation on difficult terrain, especially as it relates to skyline tension and radio signals.

In addition, the operating conditions of the Scorpion need to be clearly defined to ensure it is fit for purpose. The most significant recommendation is that design calculations must be made on all aspects of the equipment to ensure it is capable of its intended function, and that all required modifications are made during the next stage of development prior to field trials.

2 INTRODUCTION

The goal of the Future Forests Research (FFR) harvesting research programme is to improve productivity and safety, and reduce the cost of steep country harvesting.[1] Grapple yarding is an obvious way to improve safety through eliminating use of manual breaking out from the operation. Grapple yarding can also be highly productive in good conditions where payload can be maximised. The specific aim of the FFR project, Development of Improved Grapple Carriage Control Systems, is to increase the uptake of grapple yarding in New Zealand.[2] One of the barriers to wider adoption of grapple yarding has been achieving satisfactory payload while grappling. With single grapples, commonly only one stem is grappled at a time (Figure 1).

Figure 1: A typical payload while grapple yarding.

There are several new hydraulic grapple carriages on the market in New Zealand, such as the Falcon Forestry Claw [3, 4] and the Alpine Grapple [5, 6], which are designed to improve grapple control and productivity. The advent of these new single grapple designs with hydraulic control has reinforced the need for improved payload and lateral yarding capability (by improved reach of the grapple) during grapple yarding in order to increase productivity.

In December 2012, Scorpion Limited of Napier proposed a project for FFR to co-fund the development of a new grapple design to overcome these issues. The FFR Technical Steering Team (TST) approved the concept in February 2013, subject to project plan development. The Project Plan was submitted on 29th May 2013 and approved by the TST in July 2013. The alpha prototype was scheduled to be completed by 30 April, 2014.

Scorpion Ltd has designed, and envisages manufacturing, a remote-controlled grapple carriage with two operating grapples. Called the Scorpion Grapple, this dual arm grapple facilitates the extraction of two tree stems per hauler cycle. The developers anticipate that it will result in improved safety and labour efficiencies (over manual breaking out) and increased production (compared to existing grapple designs), and address the identified barriers to wider uptake of grapples in the New Zealand logging industry.

This report documents the initial development of the alpha prototype Scorpion Grapple carriage.

3 DESCRIPTION OF THE PROPOSED EQUIPMENT

The Scorpion Grapple carriage is an innovative dual arm grapple concept designed for use in the logging industry, both in New Zealand and overseas (Figure 2).

Figure 2: Concept diagram of innovative dual arm grapple design.

The concept has several potential safety advantages over existing cable extraction systems (grapple function remotely-controlled by the "spotter"). In addition, having two grapples allows extraction of more than one tree stem per cycle, and due to its long reach, harvesting a wider area in each skyline corridor, which is likely to lead to production efficiencies.

3.1 Dimensions and Mass

The alpha prototype Scorpion grapple carriage during construction is shown in Figure 3.

Figure 3: The prototype Scorpion grapple carriage during construction.

The Scorpion Grapple carriage is approximately 6 m long x 2.45 m wide x 1.2 m high. It has two grapple arms, each 4.0 m long, giving the Scorpion Grapple 8.0 m coverage of the skyline corridor. It is designed to carry two logs of up to 100 cm diameter and 2.50 tonnes mass each. The [redacted]

3.2 Carriage

The carriage runs on two sheaves along the skyline, and houses the hydraulic power packs comprising one hydraulic pump, tank and valve bank (Figure 4). The hydraulic pump is powered by battery banks, and the hydraulic cylinders and rams controlling operation of the grapple arms are operated by a radio remote-controlled valve bank (Figure 5).

Figure 4: carriage and grapple arm hydraulic cylinders.

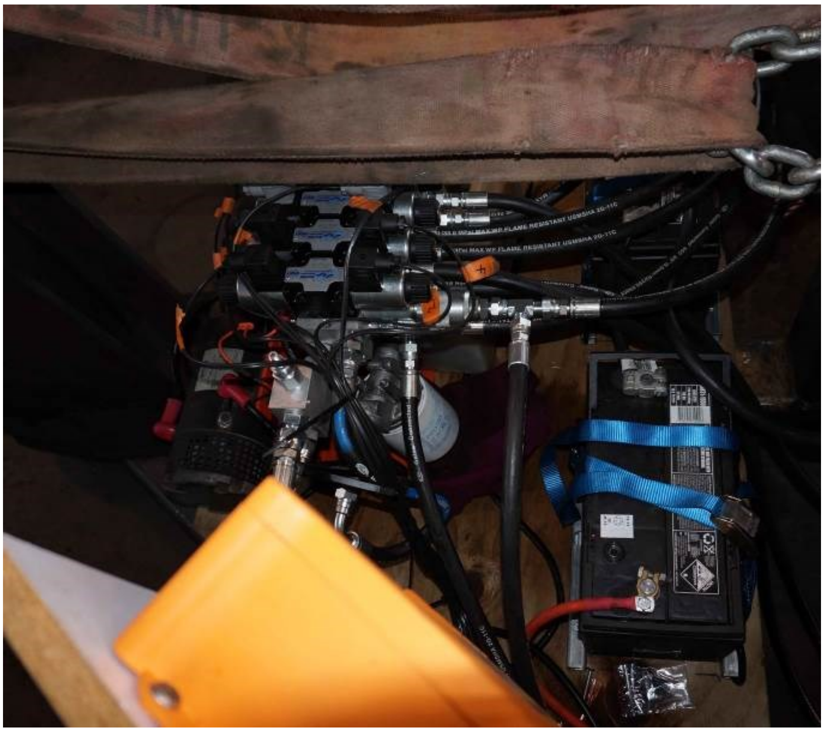

Figure 5: Battery and solenoid-controlled hydraulic valve bank.

3.3 Grapple Arms

Each grapple arm is controlled by a steering ram which articulates each arm forward and back through 120 degrees (Figure 6). A lift ram moves each arm up and down through 90 degrees. A third ram on each arm controls the opening and closing of each grapple with a rack and pin locking system to lock the grapple open (Figure 7).

Figure 6: Grapple arm pivot connection and hydraulic ram.

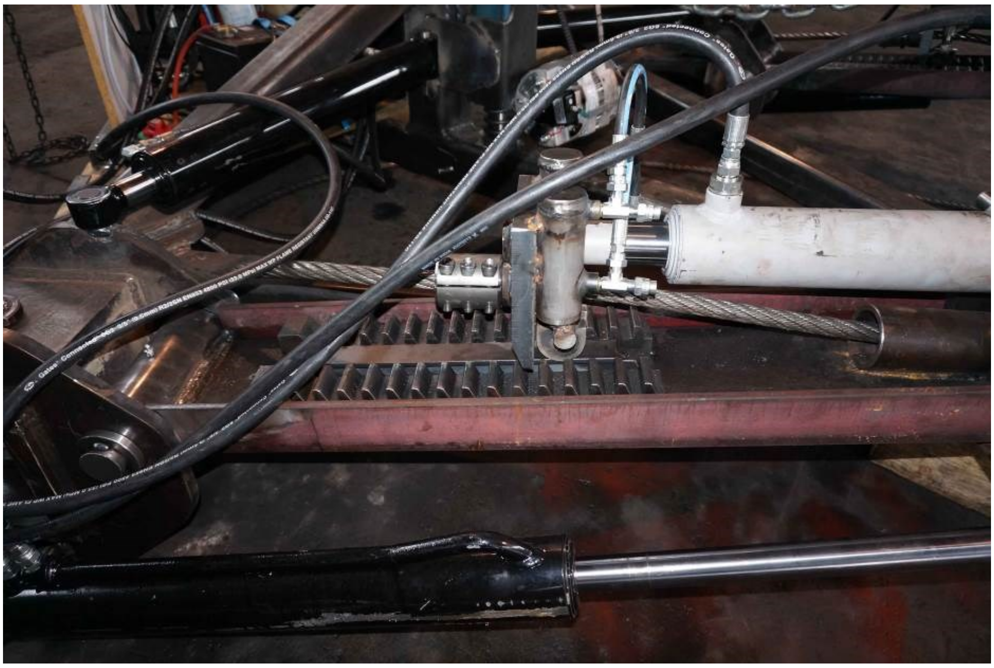

Figure 7: Grapple open/close hydraulic ram with rack and pin locking device.

3.4 Grapples

The two grapple tongs were purchased from the U.S. Each grapple is designed to handle logs of up to 100 cm in diameter and up to 2.50 tonnes mass (Figure 8). The grapple closing rope runs through the centre of each grapple arm to each grapple (Figure 9).

Figure 8: 100cm grapple opening.

Each grapple is opened by a hydraulic ram (and spring), and when the grapple is positioned on the log, the grapple closing rope is tightened by the hydraulic ram and locked into position.

[redacted]

3.5 Operation

The Scorpion Grapple carriage is operated by remote control (Figure 10). The hand-held remote control unit is operated by a “spotter”, and this allows the spotter to operate the grapple carriage at safe working distances and guide the hauler operator to work safely. The spotter will communicate via a radio with the yarder to send the carriage out (outhaul). As the carriage reaches the target area the spotter will signal to stop.

Figure 10: Carriage remote control.

The spotter can then manipulate each arm by remote control unit (Figure 11), allowing the grapple to drop on to the log in the target area and grapple it.

Figure 11: Hand-held joystick controller.

Once each tree stem has been grappled, the spotter signals for the carriage to be in-hauled, tightening the grapple on the log and fully supporting the weight of the stem.

4 APPRAISAL METHOD

The alpha prototype Scorpion Grapple was built during early 2014. Part of the project was to commission an independent consultant engineering report to review the engineering feasibility of the Scorpion Grapple design. Index Engineering Ltd was engaged to provide an appraisal report with the following considerations:

1. Identify possible potential problem areas in respect of the overall concept:
    - Mechanical design
    - Hydraulic system
    - Electrical & electronic system

2. Recommendations to resolve the identified problems.

3. General recommendations regarding the concept and design of the Scorpion Log Grapple.

Index Engineering Ltd had been supplied with copies of the initial presentation to the FFR Technical Steering Team and a copy of the Project Proposal (dated 29 May 2013). Mr Jan Snyman from Index Engineering Ltd, Rotorua travelled to the Scorpion Limited workshop at Steelworks, 2 Cadbury Street, Onekawa, Napier on 17th April 2014 to inspect the prototype.

On-site discussions were held with Scorpion Limited directors, Mr Steven Palmer, and Mr Gary Jones and one of their staff, Mr Allan McLean. Photos were taken on-site and are included in this report. The alpha prototype Scorpion Grapple had not been field tested as at 17 April 2014, so a second site visit was made on 31st May 2014. The intention was to observe the Scorpion operating in a forest setting, but this could not be achieved. Instead the visit comprised a site inspection. Index Engineering Ltd observed that a large amount of work had been done since the last inspection in April. Aspects of the mechanical, hydraulic, electrical and electronic system were assessed, and 26 recommendations have been made.

Once development of the alpha prototype is completed, full production field trials are to be conducted by Scorpion Ltd and Future Forests Research Ltd (FFR) later in 2014.

5 RESULTS OF APPRAISAL

As a result of the assessment, general comments are made about the concept and design; then follows the identification of a number of issues or potential problem areas. The problems that have been identified as more critical have been identified first. Each issue has been set out with a relevant recommendation as to how Scorpion Limited should resolve the issue, or at least provide questions that the designers need to address during further development.

5.1 Concept and Design

Overall the concept of a longer reach grapple allowing harvesting of a wider area at any one time (lateral yarding capability) and the method that is used is a good concept.

There are many potential safety advantages of this system including:

- workers don't need to work directly with the logs but can do so from a distance;
- the grapple has "spikey" claws which will grab the logs resulting in less chance that logs will fall; and
- the control of the grapple actions by manual remote controls for both loading and unloading the grapple.

Index Engineering Ltd agreed with Scorpion Limited's assessment that there will be less wear and tear than on existing units, and that it will be possible to utilise the existing rigging in most cable logging operations.

5.2 Transportation and Assembly

The Scorpion is approximately 6.0 m long x 2.45 m wide x 1.2 m high, and weighs approximately 1500 kg. The width of the carriage is close to the maximum allowable standard width for transportation (2.5 m), and could be seen as an extra wide load. To overcome this issue the carriage will need to be positioned on an angle to be within the trailer width.

In the opinion of Index Engineering Ltd, there could be an issue with transporting the Scorpion. Due to its size and weight, it appeared likely that the Scorpion would need to be dismantled into the body and two arms for transportation. This may lead to the risk that parts could get lost/go missing (e.g. pins/bolts) during transporting. In addition, it means that technical expertise will be needed for dismantling / reassembling.

Also there could be an issue with reassembling the equipment, due to the weight of the various parts; that is, they are too heavy for one person to handle. If no loader is available, a crane would be needed to lift the arms into place in order to reassemble it. It is possible that, due to terrain issues, a crane may not always be able to access the area where the carriage is to be positioned. This could be a significant issue or limitation to the design. In addition, the use of a crane is likely to incur an extra cost and manpower resource if it is not already in the forest at that point.

5.2.1 Recommendation: Transportation and Assembly

Index Engineering Ltd recommended that options for transportation and assembly are fully assessed and costed out. This should include an investigation of the option of keeping the carriage and grapples fully assembled, and moving it to site on a low bed or trailer.

5.3 Centre of Gravity of the Carriage

The Scorpion grapple carriage has two grapple arms, each 4.0 m long, and is designed to carry two logs each hauler cycle. The logs will not be symmetrically located around the carriage when picking up, i.e. the logs will be scattered and at times there will be more logs to pick up on one side of the body than the other side. In the opinion of Index Engineering Ltd, there is likelihood that the carriage will become unbalanced on the skyline (Figure 12).

Figure 12: Carriage frame and grapple arms.

An example situation is if the carriage is picking up a 2.5-tonne log on one side, and no log on the other side. To stabilise the carriage on the skyline, Index Engineering Ltd was told by Scorpion Limited that the opposite grapple arm needs to be operated (i.e. spread out) to level out the carriage. In doing so, battery power will be drawn on heavily to operate the hydraulic system when there is a need to balance the carriage. There are doubts that this method will work. Battery issues are addressed in Section 5.4.

5.3.1 Recommendation: Centre of Gravity

Index Engineering Ltd recommended that field trials are conducted to determine if the carriage becomes unbalanced when lifting logs on only one side, and/or to understand how to stabilise the carriage on the skyline most efficiently.

5.4 Battery

The Scorpion is powered from a bank of batteries, and hence the capability of each battery is a critical issue. The batteries are charged by an alternator which is driven via V belts or chain drive from the sheave on the skyline (Figure 13). The whole carriage needs to be able to move fast enough along the skyline to drive the alternator and therefore charge the batteries. It is vital that the alternator keeps the battery fully charged.

In Index Engineering Ltd's view the developers have not proven that the battery will be sufficiently charged during operation. Index Engineering Ltd is of the view that there will likely be times when the battery is not fully charged. There could be a stop-start issue with not turning the alternator fast enough to supply a continuous charge during log harvesting.

It needs to be proven whether or not general day-to-day operation will meet these minimum operating conditions. This should include an appraisal of how long the battery will last if it is insufficiently charged.

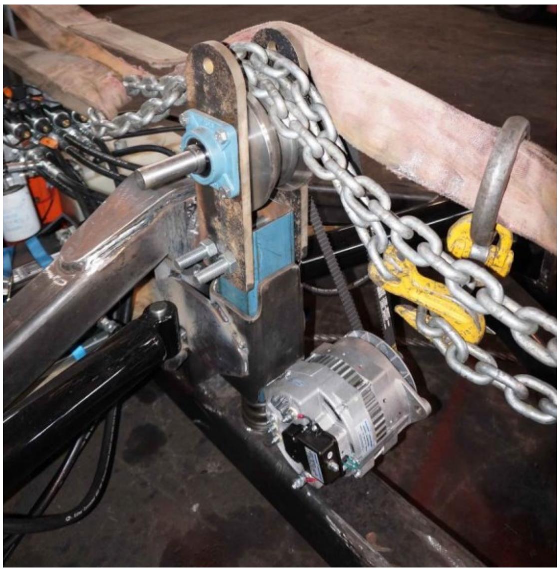

Figure 13: carriage alternator and drive pulley with V belt.

5.4.1 Recommendation: Battery charging

Index Engineering Ltd recommended that further research and development is undertaken to calculate the minimum operating conditions needed in order for the battery to remain fully charged.

5.4.2 Recommendation: Battery indicator

Index Engineering Ltd recommended that a visible alarm/light/indicator is installed to forewarn the operator when a battery is being inadequately charged during operation.

5.4.3 Recommendation: Battery contingency plan

Index Engineering Ltd recommended that a well thought out and fully costed contingency plan needs to be put in place for situations when a battery is found to be not fully charged. Such plan may include:

- how the carriage should be operated in order to bring the charge level back to full;
- how long the battery will last if it is insufficiently charged;
- an evaluation of how long it takes to change a flat battery and where/how a flat battery will be recharged; and
- having a replacement battery available at all times.

5.4.4 Recommendation: Battery restraints

Index Engineering Ltd recommended that proper cable clamps are installed to ensure the battery is clamped down adequately and that protection is provided from bumps and falls (a vibration pad fitted below the battery was suggested).

5.5 Hydraulics

If the battery runs flat, the hydraulic pump will stop working. There could also be other reasons for the hydraulic pump to stop working. If the hydraulics stop working, there could be safety issues with the grapple spontaneously releasing the logs. A contingency plan needs to be developed for the operators in the event that the hydraulic pump fails. Sufficient oil filters are needed due to the [redacted]

5.5.1 Recommendation: Hydraulics not operating

Index Engineering Ltd recommended that field testing is undertaken of the situation when the hydraulics do not work.

5.5.2 Recommendation: Hydraulic pump failure

Index Engineering Ltd recommended that a contingency plan be developed in the event that the hydraulic pump fails, and releases the clamping pressure of the grapple on the log.

5.5.3 Recommendation: Hydraulic componentry

Index Engineering Ltd recommended that all hydraulic equipment (i.e. hydraulic fittings, hoses and pumps) should be specified as standard "off the shelf" (OTS) items (Figures 14 and 15).

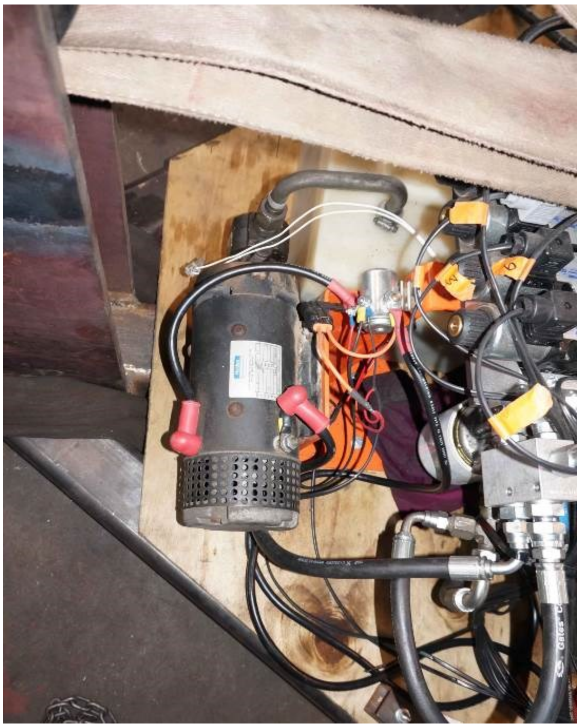

Figure 14: Hydraulic pump.

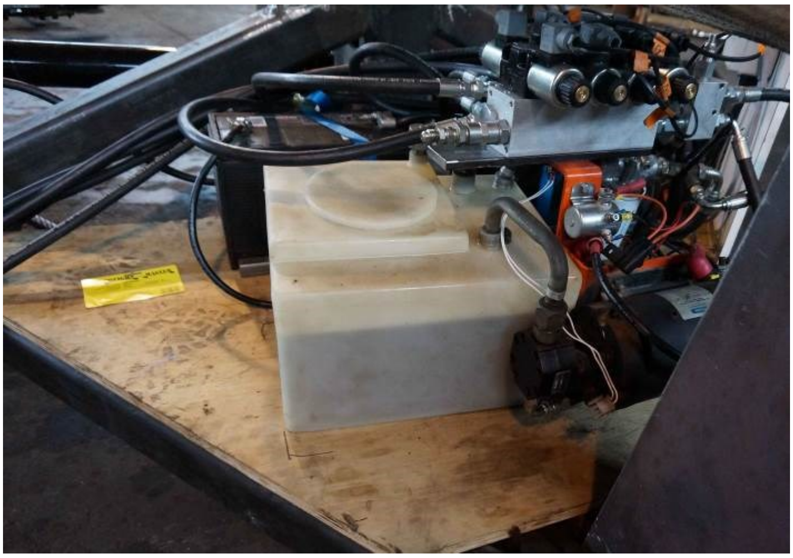

Figure 15: Hydraulic oil tank.

5.5.4 Recommendation: Oil Filters

Index Engineering Ltd recommended that sufficient oil filters are installed.

5.6 Carriage Design Calculations

The Scorpion carriage, grapple arms and grapples are still in development stage, with the design being developed as work progresses.

While the concept of the Scorpion grapple carriage appears sound, design calculations are critical for all aspects of the Scorpion Grapple to ensure that it is capable of its intended functions. The calculations may indicate design changes need to be made.

Areas for design calculations include: hydraulic pump, design checks for intended clamping force/load on rams, hydraulic cylinder calculations, cylinder mounting clevis and pins, rake and gear designs, sheave size and dimensions of sheave supports. The hydraulic tank size needs to be calculated so as to be large enough to supply the correct amount of hydraulic oil to the cylinders. The valve banks and solenoids need to be properly sized. The skyline cable dimensions, and the maximum breaking strain and safe working load of the cable need to be determined and checked with what is actually used in the field.

Full detail engineering drawings will be required when moving onto the next phase (manufacturing). Other aspects that require design calculations are included in sections 5.8 and 5.11 of this report.

5.6.1 Recommendation: Design calculations

Index Engineering Ltd recommended that design calculations are undertaken for all aspects of the carriage design.

5.7 Terrain

The positioning of the carriage on difficult terrain could be an issue. Difficult terrain such as deep gullies or convex slopes could affect visibility, radio remote control signals, skyline tension and carriage clearance from the ground. Unimpeded communication between the hauler operator and the grapple carriage operator (spotter) is vital. The spotter needs to be able to see how the equipment is working from at least two tree lengths away (50-70 m). This visibility will be affected by terrain, vegetation, weather, and light conditions. In addition, conditions of poor deflection will result in increased skyline tensions and reduced payloads.

A range of situations need to be evaluated to determine whether carriage weight (including payload) and rope tension could be limiting factors on the area of terrain (width of skyline corridor) that can be harvested. Field testing in a variety of conditions will be useful in this regard. Operating conditions of the Scorpion Grapple need to be defined in such a way that the operators can determine whether or not the correct skyline tensions have been maintained.

In addition, expert advice is needed on whether the radio controls and signals will be adequate over distance and with obstacles. If they are not, this issue needs to be resolved. Adequate lighting should also be installed.

5.7.1 Recommendation: Skyline tension

Index Engineering Ltd recommended that field trials need to be done to determine the correct skyline rope tension in order for the carriage to move freely along the skyline.

5.7.2 Recommendation: Operating conditions

Index Engineering Ltd recommended that the operating parameters and performance specifications of the Scorpion Grapple need to be clearly defined and evaluated against likely field conditions to determine if it is fit for purpose.

5.7.3 Recommendation: Radio controls

Index Engineering Ltd recommended that expert advice is sought on the adequacy of the radio remote controls and signals in the proposed terrain.

5.7.4 Recommendation: Lighting

Index Engineering Ltd recommended that adequate lighting is fitted on the carriage.

5.8 Structural and Mechanical Issues

No issues were identified with the structural members and plates used. Structural and mechanical components appear well designed/over-designed. Some changes had been made when Index Engineering Ltd inspected the Scorpion log carriage for the second time on 31st May 2014. In particular there were fully welded structural joints, bottom protection plates, painted structural components, pins on the pulleys had been replaced and there were improvements in the hydraulic piping mounting.

On first inspection of the carriage on 17th April 2014, the grapples were not open to their full extent – i.e. only to a width of 750 mm, rather than the 1000 mm capacity. The 1000 mm opening was achieved only with human intervention in the workshop. This was considered to be an issue that needs to be addressed. The grapples need to be able to be opened to their full extent (Figures 19 and 20). It could be that the hydraulic cylinder was not engaging with the grapple cable. Alternatively, it could be that the Scorpion grapple spring and tension arms need to be adjusted or altered.

5.8.1 Recommendation: Grapple

Index Engineering Ltd recommended that the grapples be able to be opened to their full extent (maximum 1.0 metre opening) by hydraulic/mechanical control only.

The grapple opening and closing cylinder appears to be adequate for purpose. Design calculations need to be done to identify, for example, the clamping force of the grapples to ensure that they are adequate for the intended loads. In the view of Index Engineering Ltd, the two hydraulic rams controlling the hydraulic arms could be undersized. No design data was available.

5.8.2 Recommendation: Design calculations on structural components

Index Engineering Ltd recommended that design calculations are undertaken for all the structural and mechanical components including the clamping force of the grapples, the hydraulic rams, and the wire rope attachments (end connectors).

The rack and pinion appears to be well designed. The two small cylinders lifting the locking plate in to the rack once the grapple is closed were working well and in full contact when locked (Figure 22). The wire rope controlling each grapple (open/close) runs through each grapple arm. This will require complete removal for inspection. Wire rope attachments will need to be checked regularly (wear, number of strands, diameter of rope for the load etc.). Rope attachments, shackles and thimbles need to be standard “off the shelf” (OTS) items. The grapples can rotate 360 degrees (both directions) when lifting logs. This rotation could unwind the steel wire ropes and strands connecting the grapples to the hydraulic rams. A mechanical stop is required to limit the grapple rotation. The thrust bearing connections on the grapple arms were working well. Bearings need to be detailed and specified, to make replacement easy.

5.8.3 Recommendation: Grapple rotation

Index Engineering Ltd recommended that a mechanical stop is required to limit the grapple rotation and prevent the wire ropes connecting the grapples to the hydraulic rams becoming unwound.

5.8.4 Recommendation: Bearings

Index Engineering Ltd recommended that specifications and detailing on bearings are set out.

5.9 Welding

During manufacture, care needs to be taken in achieving adequate welds. All sharp corners needed to be rounded to prevent stress points and cracking. All critical structural welds need to be NDT tested. Quality control documents should be kept and welding should be done by a NZ-approved structural codes welder or an ASME 9 certified welder (Figure 16).

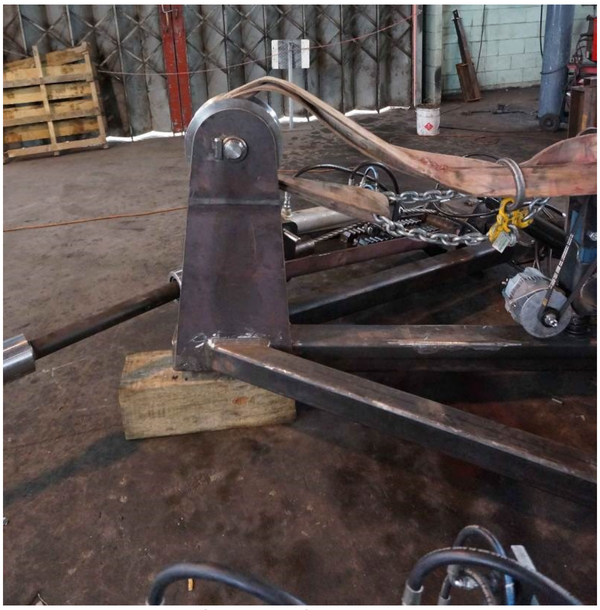

Figure 16: Carriage frame construction.

5.9.1 Recommendation: Welding

Index Engineering Ltd recommended that during manufacture, adequate welds are achieved including NDT testing for critical welds, sharp corners are rounded and all welding is done to NZ Approved Welding Code.

5.10 Lubrication

Greasing of all moving parts is needed – springs, sprockets, ropes, pins, bearings, knuckle joints, roller mechanisms. Grease nipples should be installed, or some other alternative method for lubrication needs to be considered. Oil changes for the hydraulic system need to be programmed.

5.10.1 Recommendation: Lubrication

Index Engineering Ltd recommended that grease nipples or alternative methods for lubrication are incorporated into the Scorpion carriage and grapple arms.

5.11 Electronics

The spring loaded sheave needs to be in contact all the time with the skyline in order to drive the alternator to charge the battery. Based on viewing the equipment, Index Engineering Ltd formed the view that the rap angle of the pulley may be too small. Scorpion Limited stated that the ratio was 3:1. The ratio between the drive and V belt pulleys needs to be calculated in order to ensure that it is correct (Figure 17). Also, due to the robust logging environment, all the electric and electronic hardware should be in a sealed, waterproof and shockproof enclosure.

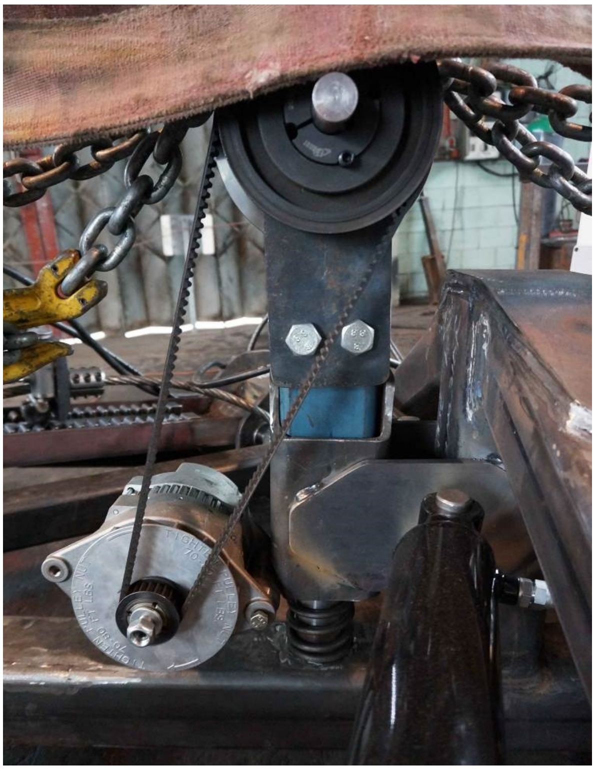

Figure 17: 3:1 ratio of alternator and drive sheave.

5.11.1 Recommendation: Alternator

Index Engineering Ltd recommended that design calculations are undertaken for the ratio between the drive and V belt pulley to ensure rotational speed is correct to drive the alternator.

5.11.2 Recommendation: Electronics

Index Engineering Ltd recommended that all electric and electronic hardware should be protected in a sealed and waterproof enclosure.

5.12 Guarding

The Scorpion drive controls, battery and hydraulics, including the cylinders, needs to be adequately protected in the event of the carriage being dropped. It is recommended that a 5-mm-thick steel plate be welded under the carriage body as protection. All moving, rotation and pinch points need to be guarded.

5.12.1 Recommendation: Guarding

Index Engineering Ltd recommended that all moving, rotation and pinch points are guarded.

5.13 Operating and Maintenance Documentation

Manuals will be required for operating and maintaining the Scorpion Grapple, and will need to include the operational setup for different terrain. A maintenance manual is required for mechanical and electrical maintenance and repairs to the Scorpion. This needs to include all detailed drawings, parts lists and materials specifications, as well as programmed oil changes and lubrication, and a hydraulic schematic diagram and an electrical schematic diagram

5.13.1 Recommendation: Operating Manual

Index Engineering Ltd recommended that an operating manual is developed.

5.13.2 Recommendation: Maintenance Manual

Index Engineering Ltd recommended that a maintenance manual is developed for maintenance and repairs and includes detailed drawings, parts lists and materials specifications as well as programmed maintenance and hydraulic and electrical schematic diagrams.

6 SUMMARY OF RECOMMENDATIONS

The following is a summary list of the recommendations made by Index Engineering Ltd:

Section 5.2 Transportation and Assembly

5.2.1 That options for transportation and assembly are full assessed.

Section 5.3 Centre of Gravity

5.3.1 That field trials are conducted to determine if the carriage becomes unbalanced when lifting logs on only one side, and/or to understand how to most efficiently stabilise the unit.

Section 5.4 Battery

5.4.1 That further research and development is undertaken to calculate the minimum operating conditions needed in order for the battery to remain fully charged.

5.4.2 That a visible alarm/light/indicator is installed to indicate when a battery is not being fully charged.

5.4.3 That a contingency plan is put in place for situations when the battery is not fully charged.

5.4.4 That the battery is clamped down adequately and protected from bumps and falls.

Section 5.5 Hydraulics

5.5.1 That field testing is undertaken of the situation when the hydraulics are not working.

5.5.2 That a contingency plan be developed in the event that the hydraulic pump fails, and releases the clamping pressure of the grapple on the log.

5.5.3 That all hydraulic equipment should be specified as standard “off the shelf” (OTS) items.

5.5.4 That sufficient oil filters are installed.

Section 5.6 Carriage Design Calculations

5.6.1 That design calculations are undertaken for all aspects of the carriage design.

Section 5.7 Terrain

5.7.1 That field trials are undertaken to define the correct skyline rope tension for efficient operation.

5.7.2 That the operating conditions of the Scorpion grapple carriage are clearly defined and evaluated against likely field conditions.

5.7.3 That expert advice is sought on the adequacy of the radio controls and signals in the proposed terrain.

5.7.4 That adequate lighting is fitted on the carriage.

Section 5.8 Structural and Mechanical Issues

5.8.1 That the grapples be able to be opened to their full extent (1.0 metre) by hydraulic/mechanical control only.

5.8.2 That design calculations are undertaken for all the structural and mechanical components, including the clamping force of the grapples, the hydraulic rams and the wire rope attachments.

5.8.3 That a mechanical stop is required to limit the grapple rotation and/or to prevent the wire ropes becoming unwound.

5.8.4 That specifications and detailing on bearings are set out.

Section 5.9 Welding

5.9.1 That, during manufacture, adequate welds are achieved including NDT testing for critical welds, sharp corners are rounded and all welding is done to NZ Approved Welding Code.

Section 5.10 Lubrication

5.10.1 That grease nipples or alternative methods for lubrication are incorporated into the Scorpion carriage and grapple arms.

Section 5.11 Electronics

5.11.1 That design calculations are undertaken for the ratio between the drive and V belt pulley to ensure rotational speed is correct to drive the alternator.

5.11.2 That all electric and electronic hardware should be protected in a sealed and waterproof enclosure.

Section 5.12 Guarding

5.12.1 That all moving, rotation and pinch points are guarded.

Section 5.13 Operating and Maintenance Documentation

5.13.1 That an operating manual is developed.

5.13.2 That a maintenance manual is developed for maintenance and repairs and includes detailed drawings, parts lists and materials specifications as well as programmed oil changes and lubrication, and a hydraulic schematic diagram and an electrical schematic diagram.

7 CONCLUSION

In Index Engineering Ltd's view, the overall concept of the Scorpion Grapple carriage appears sound, particularly in relation to the safety advantages of this system. The concept of harvesting a wider area at any one time is likely to lead to production efficiencies and cost savings.

At the current point of development, Index Engineering Ltd is not yet satisfied that the Scorpion Grapple is technically feasible for the following reasons:

1) More explanation or demonstration is needed relating to the practicality of getting the Scorpion grapple carriage to its correct positioning on site, given its larger size and weight than the equipment in current use in the forestry industry.
2) That there is likelihood that the unit will become unbalanced on the skyline.
3) There has been insufficient evidence provided that the battery will be fully charged during operation.
4) More work is needed to determine how the Scorpion carriage will operate on difficult terrain; in particular, attention needs to be given to the skyline tension and radio signals.

Index Engineering Ltd considers that more work is needed to fully analyse, calculate, explain or address the above issues. Index Engineering Ltd considers that it is important that the operating parameters and performance specifications of the Scorpion grapple carriage are clearly defined, in order to determine whether it will be fit for purpose.

In addition, Index Engineering Ltd considers that it is critical that design calculations are undertaken on all aspects of the machinery, to ensure that it is capable of its intended functions. The grapple opening capacity was not achieved when Index Engineering Ltd viewed the equipment – this needs to be rectified. Specific manufacturing detail issues have been identified in this report, which must be addressed in the next stage of development prior to the field trial stage.

8 REFERENCES

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