HARVESTING TECHNICAL NOTE

HTN09-07
2017

Tension Monitoring of Winch-Assist Systems: Update

Summary

Over 65 winch–assist machines are currently operating in New Zealand, and they are expected to comply with the Approved Code of Practice requirements. A previous study showed that winch rope tensions sometimes exceeded safe working load, and that the systems were experiencing shock loads associated with machine movement. Equipment manufacturers and contractors have continued to improve the systems and operating practices. In this update to the earlier study, measurements of rope tensions during normal operations of the three main winch-assist systems were carried out. The results confirmed that the absolute tension is dependent on the setting chosen by the operator. All systems approached safe working load during operations, and in some instances this was exceeded. The overall finding was that the machines tested were able to manage rope tensions within the safety factor specified in the Approved Code of Practice. Shock loading was still evident, combined with high tensions, and it is recommended that incidents of high tension be recorded and monitored to minimise the risk of winch rope failure through accelerated fatigue.

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INTRODUCTION

Winch-assisted felling systems can improve both safety and productivity. These systems are supporting the growth of mechanisation in steep slope harvesting by providing both a safer and more productive platform for tasks such as felling, shovelling or bunching ahead of cable yarder extraction (Evanson and Amishev, 2009).

Winch-assist harvesting operations have developed quickly in New Zealand. There are now four main winch-assist equipment models manufactured in New Zealand: the Tractionline by Electrical and Machinery Services Ltd (E.M.S. Ltd); the Falcon Winch Assist by D.C. Equipment Ltd; the Remote Operated Bulldozer (ROB) by Rosewarne & May Ltd; and the ClimbMAX Steep Slope Harvester by ClimbMAX Equipment Ltd.

From the first commercial model available in October 2012, the number of systems operating in New Zealand has increased to over 65 as of June 2017. In addition each company has had export success with over 50 machines exported in total, primarily to British Columbia in Canada, Washington state, U.S.A., and Chile in South America.

As the systems have become more advanced in design, more detailed operating manuals have been developed by the manufacturers. Also, as forestry companies have become more extensively involved in managing winch-assist operations they have continued to develop Best Practice Guidelines. Examples include Hancock Forest Management (NZ) Ltd (Theobald, 2016), and Rayonier Matariki Forests (Dempster, 2015). WorkSafe NZ also issued a fact sheet (WorkSafe NZ, 2016) providing further clarity to the section in the Approved Code of Practice for Safety and Health in Forest Operations (ACOP) regarding winch-assist operations (MBIE, 2012). Visser and Stampfer (2015) have also provided a comprehensive overview of the development of winch-assist systems, including the safety aspects of operating on steep slopes.

Earlier tension monitoring tests were undertaken on the first system developed by innovative contractor Ross Wood of Wood Contracting Nelson Ltd in 2013 to provide early indications of shock loading on the system (Visser, 2013). The earlier tests not only showed incidents of significant shock loading, but also showed the system sometimes exceeded the safe working load (SWL) of the winch rope. Subsequent tests on the ClimbMAX harvester in 2013 (Evanson *et al.* 2013) paired the tension data with time-and-motion information, and clearly linked the incidence of shock-loading to the movement of the machine. The observed tension behaviour was confirmed by further tests carried out on a number of other winch-assist machines (Schaare *et al.* 2016).

One limitation of the previous studies was that only two of the 'mainstream' systems (the ROB and ClimbMAX) were tested. As such it was considered important to measure the tensions of the winch-assist machines manufactured by all the main commercial suppliers (E.M.S. Ltd, D.C. Equipment Ltd and Rosewarne & May Ltd).

OBJECTIVES

The primary objective of this study was to test the wire rope tension during normal operations of the three most common winch-assist systems in New Zealand.

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METHODS

Description of Systems

Three systems were studied: the Tractionline, the Falcon Winch Assist, and the Remote Operated Bulldozer ('ROB').

Both the Tractionline and the Falcon Winch Assist machines are retro-fitted excavators. The ROB is a twin winch-system mounted onto the back of a bulldozer, as the name suggests (Figure 1).

Figure 1: Remote Operated Bulldozer (ROB) system.

The Tractionline and the ROB are both two-rope systems, using 22-mm power swaged and swaged ropes respectively. The Falcon uses a single 28-mm swaged rope.

The Tractionline system runs both cables from the winches at the rear of the excavator up and over the boom and down through a pivoting sheave located close to the bucket (Figure 2).

Elements of this system include: twin cable winches, 2 x 350-m lengths of 22-mm cable, excavator boom extension with two built-in sheaves, and a pivoting double sheave attachment at the bucket and of the boom.

Figure 2: Tractionline system.

The Falcon Winch Assist is similar to the Tractionline system, except that it has a single winch running the cable from the winch at the rear of the excavator up and over the boom (Figure 3). Similarly, both systems can be retrofitted to a variety of new and used machines.

Figure 3: Falcon Winch Assist.

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All provide an operating system that manages winch settings in the machine on the slope (see example of ROB system in Figure 1), and all include a read-out of the rope tension.

All three systems have an integrated tension monitoring system. The Falcon uses a load pin through the sheave mounted at the top of the boom to measure the tension (Figure 4). This tension monitoring system shows the angle at which the stick of the excavator should sit in order to ensure stability. This improves the accuracy of the tension measurement as there is a correlation between the actual rope tension and this angle.

Figure 4: Load pin sheave for monitoring tension.

The Tractionline system measures the hydraulic pressure in the drums. This is calibrated to the tension in the rope, but remains an indirect measure of actual rope tension, as tensions are back-calculated. However, the calculation does take into account the amount of wire rope spooled onto the drum, as well as the drive gearing ratios (Figure 5).

Figure 5: Tractionline tension display system.

The ROB system has two sets of deflection sheaves mounted on the bulldozer's blade at the front of the unit that measure rope tension (Figure 6). Deflection sheaves put a small bend ('bight') into the rope, and the pressure on the sheave is correlated to the rope tension.

Figure 6: Tension monitor sheaves on the ROB system.

Data Collection

Testing the Falcon system was done with the support of the DC Equipment Ltd team. The researchers were able to link a PT200M Digital Indicator and laptop computer with data logging software directly to the load pin. This allowed for tensions to be directly downloaded at a rate of 10 Hz.

For the Tractionline and ROB systems, researchers were not able to directly record tension, and a GoPro camera was mounted and directed onto the output display to capture the data for both ropes (Figure 7). The video was then transcribed at a rate of 4 Hz (Tractionline) or 5 Hz (ROB) into a spreadsheet. Schaare *et al.* (2016) showed that capturing data at 4 Hz would be sufficient to measure the magnitudes of shock loads that occur at less than 0.5 seconds.

Figure 7: GoPro camera view for recording working tensions.

Study Sites

The test using the ROB system was carried out with two different crews in two different locations in Northland. The first site was located in Pouto Forest, south of Dargaville. This site had smooth consistent slopes averaging 45% (24 degrees) and sandy loam soil.

The second site was located in Opouteke Forest, North of Dargaville, and had straight slopes averaging 50% (27 degrees) with heavy undergrowth on soft clay soil (Figure 8).

Figure 8: ROB study site, with yellow line showing the position of the ropes.

A tree was being used to significantly deflect (>90 degrees) the direction of the ropes (Figure 9). It created a strong bind in the tree for both ropes.

Figure 9: ROB winch-assist machine set-up, with yellow line showing ropes wrapped around tree.

The Falcon system was tested in the Nelson region, in Hira Forest, with 55% (29 degrees) average slope and rocky soils (Figure 10).

Figure 10: Falcon study site in Nelson.

The Tractionline system was tested in collaboration with FP Innovations in Washington State, USA. The study site had smooth, straight slopes averaging 65% (33 degrees) with a maximum distance of 250 m (Figure 11).

Figure 11: Tractionline study site in Washington, USA.

RESULTS & DISCUSSION

The tensions measured in each of the machines are a resultant combination of the machine capability, the operator-selected winch-assist setting, and the operating practices employed by the operator. As such the results provide only a snap-shot of the rope tensions experienced during felling operations. While many hours of data were captured, only selected segments are shown in this report to illustrate different operational aspects and their influence on rope tension.

E.M.S. Tractionline

For longer periods of work, the operator chose a setting of approximately 10 tonnes in both ropes (for a total of 20 tonne winch-assist force). Figure 12 shows working tensions on the two ropes (blue and orange lines on the chart), with movement intervals included by the green line: a movement value of 0 = stationary, 1 = downhill, and 2 = uphill.

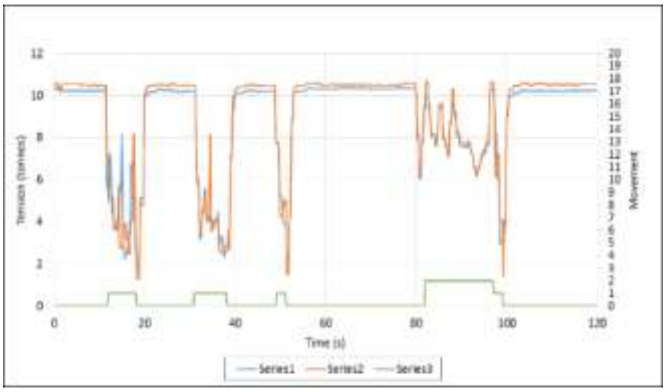

Figure 12: Tractionline rope tensions during felling machine movement (shock loads below base tension).

A positive feature is that the loading on both ropes is synchronised. That is, both ropes are responding to both the winch and external settings identically at the sub-second frequency. While the machine is stationary and working on the slope the winch pressure is also very constant. With the tension being dropped at the start of movement, the shock loading caused by the movement of the machine on the slope starts at a much lower value (3-5 tonnes), but the magnitude of the shocks are in the order of 4-5 tonnes.

Figure 13 shows a different phase of the operation where the tension was not dropped at time of movement. In this case a base tension of 5 tonnes in each line was selected (Winch Setting 1.5, shown by the yellow line), but the shock loads were above that. During some of the shock loading events it can be seen that there is a difference between the tensions in the two ropes. This would indicate that a rope could have been in contact with the ground or stump/tree.

In both of these tension charts (Figure 12 &13), the operator was using the auto mode of the winches. When in auto mode there are effectively only two settings, inhaul or outhaul. When the machine is stationary or travelling uphill the winch uses inhaul mode. When the operator engages the travel pedal for travelling downhill, the winch automatically switches to outhaul mode and attempts to hold the tension selected by the operator. The difference between the lower setting line (setting 1) and the higher line (setting 1.5) is shown in Figure 13.

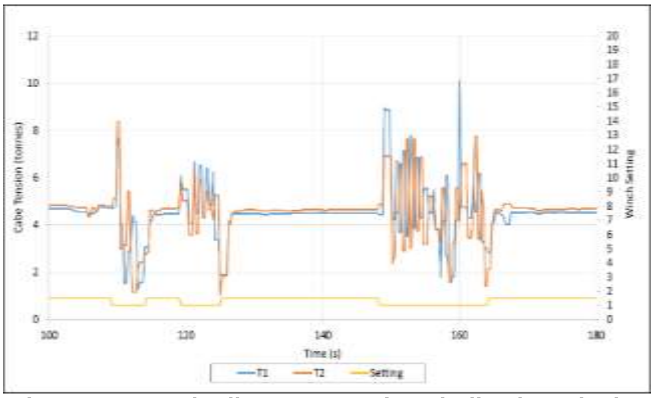

Figure 13: Tractionline rope tensions indicating winch setting, with shock loads above base tension.

Falcon Winch Assist

Figure 14 shows a brief segment (about 4 minutes) of operation of the Falcon Winch Assist machine. The winch setting had a large influence on operating tensions. The operator stated that for this section he was walking the harvester downhill using setting 4 and came back up using setting 5 and 6. When working downhill (felling and bunching), this equated to tension of about 7 tonnes, and then for a 2-minute period at the end, the higher setting chosen equated to about 18 tonnes of pull.

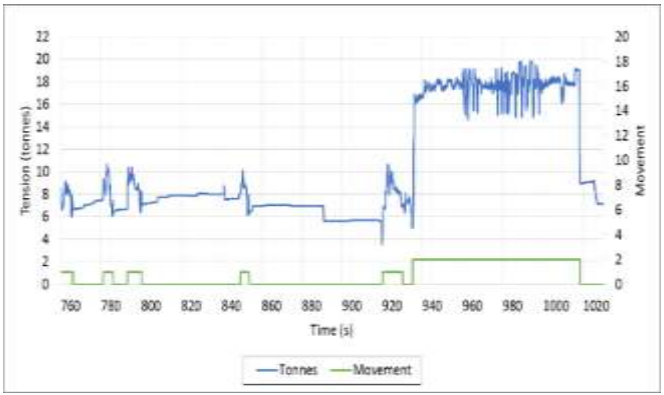

Figure 14: Falcon rope tension when moving downhill then uphill, with shock loading above base tension.

Overall the shock loading measured during this operation was relatively low, but clearly coincided with machine movement. The tensions are higher when moving downhill (approx. 4 tonnes) then when moving uphill (approx. 2 tonnes). This can be readily explained in that, in addition to the gravity acting on the machine, a larger tracked machine will be pulling the rope off the winch when moving downhill. As for all systems, it is important that the system is calibrated correctly. A short calibration test on the Falcon was undertaken using a 28-mm swaged 6 x 26 IWRC rope with a rated breaking strength of 71.2 tonnes, and SWL of 23.7 tonnes, using a Factor of Safety (FoS) of 3. Results showed that when in Setting 7 and 8, the tension exceeded SWL initially then reduced to within SWL (Figure 15).

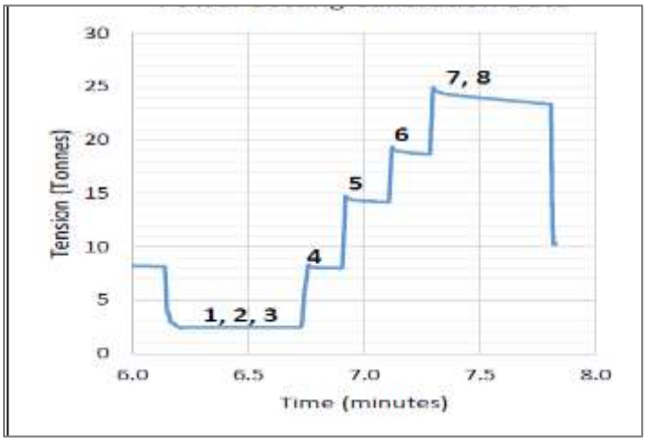

Figure 15: Falcon winch power setting calibration test, with winch settings 1-8 indicated by bold text.

With regard to managing tensions, not only does each rope have a different rated breaking strength, but different manufacturers use different FoS. For example Tractionline is rated to FoS of 5. While the FoS can be used to account for unexpected levels of shock loading, both the manufacturer and operator should be aware of the normal level of shock loading and ensure the settings available to the operator allow for this and are still able to operate within SWL.

Remote Operated Bulldozer (ROB)

The two-rope ROB machine showed very stable and consistent tension characteristics when operating on the slope. While the two ropes often behaved similarly, there were certain cases where they were quite different. Figure 16, shows an example of a period of unbalanced tensions between the two ropes. The most that the two ropes differed was just under two tonnes. However, the imbalance was constant during both moving and non-moving phases of work and changes from one rope to the other.

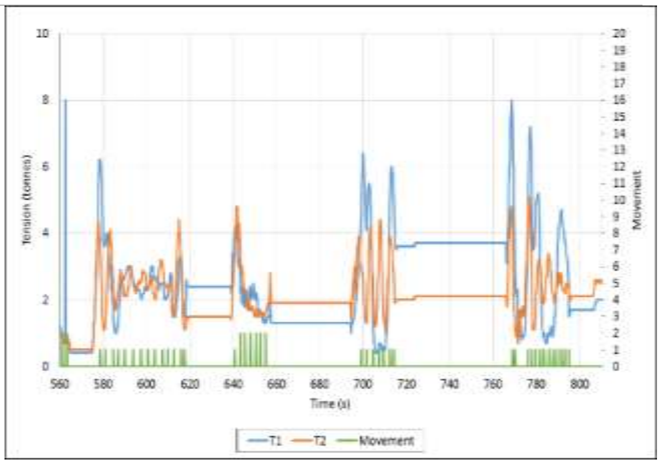

Figure 16: ROB tensions with new operator.

In some cases the shock loads are in the order of more than four tonnes. The observed tension behaviour was believed to be more influenced by the operator than by winch settings or site conditions.

The operator had just undergone an induction and this was the first attempt at harvesting while being winch-assisted. The slopes were moderate (averaging 45%) with smooth terrain and there were no observed instances of redirecting ropes around trees. It is suggested that the imbalanced tensions could be a result of the machine rocking or being skewed on the slope where one track is used more than the other to turn the machine and the two separate hitch points on the drawbar (Figure 1) created some leverage (Schaare *et al.* 2016).

At the second study location, the two ropes were being redirected around a tree at the top of the slope, creating a significant bind on the tree (Figure 9). Figure 17 shows the effect of the tree bind, where T2 is the right hand rope which had greater contact with the tree than T1 (left hand rope).

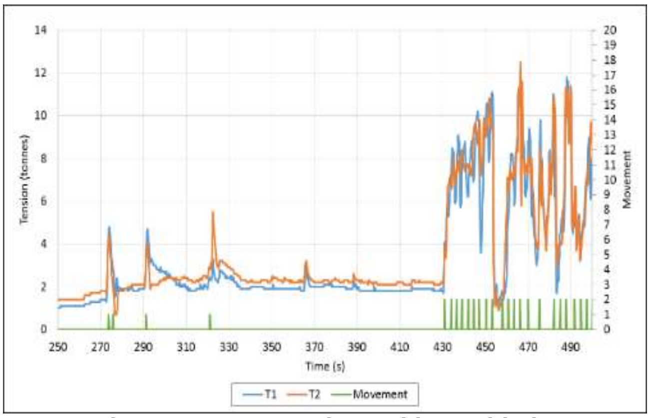

Figure 17: ROB tensions with tree bind.

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This may explain why T2 had slightly greater tensions when felling and travelling downhill (from 250-430s period in Figure 17). Interestingly, when ascending the slope (from 430-500s) the shock loading in both ropes was higher in magnitude (maximum ≈7 tonnes) but was also somewhat dampened in T2. At an angle of 90 degrees the tension between the upper and lower segments of the ropes was estimated to be 35% different. This difference was exacerbated over time with the rope biting in to the tree to increase the friction (Palmer, 2016). That means if the machine is moving downhill, the tension measured in the rope and displayed in the cab will be 35% less than the actual tension in the lower rope segment.

CONCLUSION

Tests were successfully completed on each of the three main commercially available winch-assist machines. All three systems tested have an integrated display of rope tensions (including both ropes) and one even allowed direct recording of tension data. Both these functions were previously recommended by Schaare *et al.* (2016). The two rope systems displayed good control over keeping tensions equal between ropes, but these can become imbalanced based on operating techniques.

The results confirmed that the absolute tension is dependent on the setting chosen by the operator. All systems were still capable of exceeding the SWL based on winch settings, and in some instances this was exceeded during the study period. Previous tension monitoring of these types of systems found shock loads had amplifications in the order of 3-10 tonnes. The systems tested in this study showed amplifications in the order of 2 to 7 tonnes.

The overall finding was that the machines tested were able to manage rope tensions within the safety factor specified in the Approved Code of Practice. Shock loading was still evident, combined with high tensions, and it is recommended that incidents of high tension be recorded and monitored to minimise the risk of winch rope failure through accelerated fatigue.

Winch-assist systems developed by New Zealand manufacturers are continuing to evolve in both design and control systems, and new features help to regulate and monitor tensions effectively to meet ACOP safety requirements. However, their effectiveness still depends to a large extent on the interaction between the operator and the environment.

ACKNOWLEDGEMENTS

The authors would like to thank the manufacturers and logging crews who participated in the study. Also, special thanks to FP Innovations Canada for supplying data and Russell Schaare for data analysis.

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