HARVESTING TECHNICAL NOTE

Vol: 1 Number: 8
2009

Use of Tension Monitors to Estimate Payload

Summary

Tension monitors have been used in a small number of New Zealand yarder operations for some years, mainly as a safety feature for rigging systems that use a standing skyline. They have also been trialled for use on guy lines to give advanced warning of guy line anchor failure. Another potential use for a tension monitor is as a data capture tool where the recorded tension is used to predict or estimate haul size or payload to maximise productivity of the extraction system within safe limits. This report examines the potential of this application.

Tony Evanson, Scion

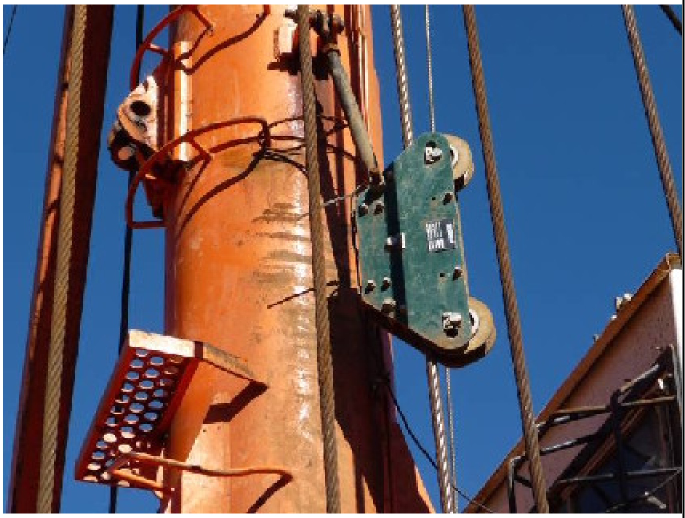

Figure 1. A Tensionright 601B Tension Monitor

Introduction

Monitoring stationary rope tensions in yarder operations is important for reasons of safety. Ensuring rope tensions remain within safe limits not only reduces rope breakage, but reducing excessive stress on the rope will maintain wire rope integrity and improve rope life.

The safe limit of a wire rope is defined by its Safe Working Load (SWL), which is calculated by dividing the particular wire rope's minimum breaking load (MBL) by the safety factor to be used.

In a study of a tension monitoring system, Smith (1992) noted that even if cable systems are carefully set up, operating conditions can result in ropes being overstressed. Smith (1992) also suggested that these stresses may not lead to immediate rope failure, but will result in reduced rope working life.

Wire rope tensions can be measured electronically using a load cell. Load cells convert a force into an electrical signal. Load cell applications involving wire rope use the "deforming" of the wire rope under load to provide the force. Manufacturers' literature indicates that these devices have many applications in the lifting industry (www.LiftCells.com.au, www.loadwise.co.uk, www.nobles.com.au).

Kronenberger and Hartsough (1992) described several methods available for monitoring cable tension, including load cells which can be inserted between a line and an anchor. In-line load cells have been reported to be both inconvenient and a possible "weak link" in the rope (Miles, Hartsough and Smith, 1988). For this reason, the Remote Tension Monitor (RTM) system developed by the Logging Industry Research Organisation (LIRO) used an externally mounted load cell (Smith,1992).

The LIRO RTM was designed to monitor guy line tension for optimum balance and stump or anchor stability, and to monitor standing skyline tension for excessive loading. The trialling of this system resulted in reductions of overload occurrences in both skylines and guy lines (Smith, 1992). Later studies of the system resulted in four out of the five operations studied being found to have increased haul volumes (of up to 8%), but the results were not statistically significant (Hartsough, 1993). The RTM system was not adopted by the logging industry at the

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

time, possibly because of its perceived high cost ($10,000).

The term “tension monitor” has gained some currency in the New Zealand logging industry (FITEC, 2000), and it is this term that is used in this report. An example of a tension monitor attached to the skyline of a cable yarder is shown in Figure 1. In logging applications, tension monitors have uses in the areas of general yarder safety (ropes and anchors), the safety-related area of calibration of skyline band-brakes, and in productivity improvement (avoiding under-loading).

Safety

With regard to safety, use of tension monitors can reduce or prevent the occurrence of broken skylines or guy lines, pulled anchors and overturned poles, by displaying the tension values to the yarder operator in time to reduce the rope’s working load. This can lead to a reduction in overloading of skylines and guy lines (Hartsough, 1993).

Rope Breaking Strength (BS)

The endurance limit of a wire rope is approximately 50% of the rope’s MBL. In some literature MBL is termed Breaking Strength, or BS. The elastic limit of steel wire rope is approximately 65% of the BS (Wenger, 1984). Elastic or Endurance Limit is so named because if a wire is given repeated pulls greater than this value, its life is comparatively shortened and it may break even if never strained to its BS or even to its Elastic Limit. For example, for a 22mm swaged wire rope the Endurance Limit is approximately 22 tonnes (Cookes, pers. comm.).

Skyline Band Brake Calibration

Integral spar yarders use a band brake to hold the skyline in tension while the hauler is working. The band brake is actuated by compressed air, and by regulating this pressure the braking action can be adjusted. The degree of torque that the brake is resisting depends on a number of factors, including the tension in the skyline, the number of rope turns on the drum, and the amount of grip between the brake linings. The latter is an important factor for a number of reasons: the lining may be subject to wear or corrosion; new linings may grip excessively; and there may be varying amounts of “spring” in the band itself.

Tension monitors can be used to calibrate skyline band brakes to slip at less than the Endurance Limit of the rope (Fraser, Palmer and Bennett, 1997). This will prevent excessive tension in the skyline, and shortened rope life.

In the calibration process described by Fraser *et al.* (1997), rope tension was read directly from the tension monitor. The authors recommended frequent calibration because of wear and tear effects on the band-brake.

Tension monitors and clamping carriages (such as Mechanical Slack Pulling, or MSP carriages)

Carriage clamps offer additional control over carriage position on the skyline, and the skyline may be clamped during slack pulling, hooking on, breaking out, and sometimes unhooking. Tension monitors can be used with clamping carriages to improve productivity and safety (Tuor, Palmer and McMahon, 1998).

From a productivity viewpoint, the haul size for a drag needs to take into account the effect on SWL of the extra weight of the carriage on the skyline. A skyline tension monitor will help ensure that haul sizes are not too conservative on the one hand, and not so large as to exceed skyline SWL on the other. This is important as the highest tensions during extraction can occur at break out.

When breaking out with the carriage clamped, resulting “imbalanced” tensions on the skyline (in front and behind the carriage) depend on the drag size, the relative positions of the drag and the carriage, and the relative positions of tower and tail hold. The tension monitor will therefore not display the “true” tension in the skyline as a whole. The extent of the imbalance depends on whether the carriage itself is in front, at right

angles to, or behind the drag at breakout. To minimise the imbalance, Tuor *et al*. (1998) suggested releasing the skyline clamp after the drag is hooked on, allowing the carriage to move forward for breakout, then clamping the skyline for inhaul. An alternative method, if the tail rope is attached to the carriage, is to tension the tail rope in opposition to the main rope forces.

The authors also noted that when the skyline clamp is released for inhaul following break out, a re-distribution of tensions takes place, and this may cause shock loading of the skyline. If using a tension monitor, this can be anticipated and factored in to ensuring operation within SWL or rope endurance limits.

Productivity

A tension monitor has been used to obtain both time study and payload data during a study of a Wyssen yarder (Bloomberg and Liley, 1985). The tension monitor was inserted in-line with a guy line on one of the intermediate supports. The tension gauge output was recorded on a pen graph trace, and total cycle time was apparent, differing from time study values by only 2%. Payload was predicted from an equation derived from tension readings for known scaled payloads (r2 = 0.75).

An additional use of rope tension monitoring is to improve productivity, as the tension values can be used to optimise haul sizes (Smith, 1992). This is primarily achieved by not "under-loading" the rigging systems with smaller than optimum payloads. However, yarder engine capacity and other limiting parameters such as braking ability may make it impractical to tension lines to the safe working load value.

Tension monitors can be used to establish the maximum payload or maximum allowable haul size (MAH) in tonnes, in standing skyline logging systems. In most cases MAH is also the optimum haul size, or the haul size most efficiently extracted (i.e. resulting in the highest productivity). The MAH is the haul size or payload which does not over-tension the skyline or mainline (Visser *et al*., 1999), hence the benefit of using a tension monitor.

Visser *et al.* (1999) reported that the MAH will vary with drag position on the haul corridor and the associated skyline deflection available at that point.

Deflection is a measure of the sag in a rope, usually expressed as a percentage of the horizontal span length. It is defined as the vertical distance between the chord and the skyline at mid-span (FITEC, 2000). This is shown in Figure 2 below.

The MAH is highly sensitive to the amount of deflection available. As tension reduces and deflection (sag) increases, more payload can be carried without rope breakage. In one calculation, a 1% increase in deflection (e.g., from 6 to 7%) coupled with a 2m increase in skyline length, resulted in a 15% increase in MAH size.

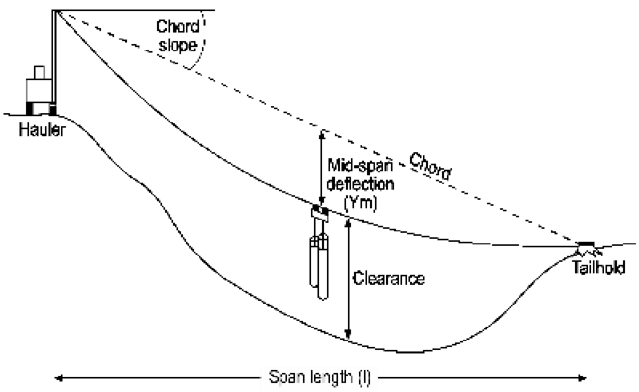

Figure 2. Measurement of Deflection.

The MAH value will also depend on the degree of load suspension required. In most "U" shaped setting profiles, skyline deflection and hence potential load capacity is greater the closer the drag is to the yarder.

Visser *et al*. (1999) noted that constraints such as spurs or ridges, and the edge of the landing need to be taken into account in estimating the

FUTURE FORESTS RESEARCH

HARVESTING TECHNICAL NOTE

Vol: 1 Number: 8
2009

MAH size. Also, that partial suspension rather than full suspension allows larger MAH sizes.

Method

- Recent tension monitoring literature was reviewed.
- Wire rope and tension monitor suppliers (Cookes, Shaw's and Brightwater) were contacted for information.
- Thirteen FFR Harvesting Theme company representatives were contacted to locate owners/users of tension monitors in the New Zealand forest industry.
- A harvesting contractor with a tension monitor in the Bay of Plenty region was interviewed and information gained on his use of the tension monitor.

Results

Types of Tension Monitors

There are two main types of tension monitor for yarders currently available – those based on deflection of the rope and sheave pin deflection (FITEC, 2000), with the former probably the most common type in use.

Figure 3. The Tensionright display with overload warning light (on the left).

Of the rope deflection type, static line monitors are available in New Zealand (from Brightwater, and Shaw's Wire Ropes) and from Australian suppliers (Liftcells). A tension monitor typically comprises two parts, the tensiometer unit and the display unit (Figure 3). A common display unit in use is made by Loadwise in the UK. Noble and Delphi Force in Australia make tensiometers and also supply load cell systems. Display systems typically read to the nearest 100kg, with accuracy affected by frequency of calibration and the effect of rope wear. Rope wear can affect accuracy by 3% to 10% (B. Daniels, Liftcells, pers. comm.) and overall accuracy is estimated at about 5%. At a SWL of 18 tonnes this is nearly one tonne, which emphasises the desirability of frequent calibration. Current versions of display available do not have data logging capability. This feature has been seen as a disadvantage by some purchasers because of the responsibility implications in the case of an accident (B. Daniels, Liftcells, pers.comm). An estimated price for the Tensionright tension monitor system is $12 000.

Use of Tension Monitors

It is estimated that some 180 yarders are currently working in New Zealand, with the majority of them probably not using a tension monitor (Gray, pers. comm.).

It is apparent that many yarder operations do not make use of tension monitors. This finding is confirmed by the responses from FFR Harvesting Theme members. Only two of the 13 theme members contacted knew of contractors using tension monitors.

Experience with a Tension Monitor

The following information was gained from a current user of a tension monitor. The tension monitor was mounted on the skyline (see Figure. 1) of a Madill 171 using a North Bend cable extraction system. The contractor used the tension monitor to activate a warning light at the SWL of 18 tonnes skyline tension. This limit was frequently reached as the haul crested a spur

with poor deflection and tail rope braking, and skyline deflection was managed to minimise these problems.

The monitor was used effectively to optimise haul sizes, as it was apparent what haul combinations produced excessive tensions. The operator noted that for a given load, with minimal interference via braking, the tensions displayed followed a repeated pattern, effectively mapping the profile.

In discussion regarding use of a tension monitor to measure payload, the issues of dynamic forces (load swinging), the lowering of the skyline, and partial suspension of payload were noted. Changes to skyline tension would effectively mean re-calibration of a payload measuring system even if dynamic forces were minimised and effects of partial suspension disregarded – for example, as the haul was lifted prior to being dropped on the landing before unhooking.

Calculating Payload from Rope Tension

In terms of using a tension monitor to estimate load size, a method by which a fully suspended, fixed skyline load can be calculated uses the following equation derived from the calculation of total rope tension (WorkSafeBC, 2006).

The load exerted on a rope is a function of the rope tension, rope deflection, weight of the rope (per unit length) and the distance of the span. The total point load is expressed as:

$$L = 4*D*T/S - W*S/2$$

Where:

L = Total Load, including carriage and logs (kg)
T = Total Tension in the skyline (kg)
D = Deflection in skyline at mid span (m)
S = Horizontal span length (m)
W = Unit weight of rope (kg/m)

Example:

The wire rope used in this example is 20mm IWRC with a MBL (Minimum Breaking Load) of 25,700kg and a weight (W) of 1.59 kg/m.

Assuming a setting where the horizontal span length (S) is 300m, and deflection (D) is 8%, (which can be expressed as 8% x 300 or 24m), if the total tension (T), as measured by the tension monitor, is 16,371 kg, then :

Total Load (L) is calculated as :

$$L = 4*D*T/S - W*S/2$$

$$L = 4*24*16371/300 - 1.59*300/2$$

$$L = 5238.7 - 238.5$$

$$L = 5000.2 \text{ kg or } 5.0 \text{ tonnes}$$

Conclusions

Cable tension monitors are useful in yarder operations in terms of ensuring that skyline ropes are used within safe working limits. Correctly used and frequently calibrated, they can help extend the life of working wire ropes.

Tension monitors can help maximise extracted haul sizes (if operators communicate effectively with breaker-outs), and in some cases can help prevent serious accidents involving rope breakage and/or tower collapse.

A calculation method is presented for using fixed skyline rope tensions to calculate maximum allowable haul size or payload. Practical application of using tension monitors to directly measure payload requires more development given the issues such as the difficulty in measuring deflection in real time, the drag effect of partial suspension of the payload, and the dynamic nature of skyline tensions during inhaul (e.g., shock loading from ground obstacles or lowering the skyline to improve deflection).

Future Forests Research Ltd, PO Box 1127, Rotorua. Ph: 07 921 1883 Email: info@ffr.co.nz Web: www.ffr.co.nz

Vol: 1 Number: 8
2009

References

Bloomberg, M. and Liley, W.B. (1985): “The Wyssen Hauler”. Limited Scale Logging. LIRA, Proceedings of a seminar, Rotorua, June 1985.

Brightwater Yarders. Supplier of Noble brand tension monitors.. http://www.brightwater.co.nz/

Cookes. Wire rope manufacturers and suppliers http://www.cookes.co.nz/

Daniels, B., Liftcells Tensiometer Systems, Australia. Personal Communication.

Delphi Force Measurement Pty Ltd. Load Cell Manaufacturers, Australia.
www.delphi-force.com.

FITEC (2000): Best Practice Guidelines for Cable Logging. Forest Industry Training and Education Council. Rotorua New Zealand.

Fraser, D., Palmer, D., and Bennett, D. (1997): Calibration of a Skyline Band Brake. LIRO Report Vol. 22 No. 21. 1997. Logging Industry Research Organisation, New Zealand.

Gray, W. Brightwater Engineering Ltd. Personal communication.

Hartsough, B. R. (1993): Benefits of Remote Tension Monitoring. LIRO Report Vol. 18 No. 23, 1993. Logging Industry Research Organisation, New Zealand.

Kronenberger, K. J. and Hartsough, B. R. (1992): A monitor for indirect measurement of cable vibration frequency and tension. Transactions of the ASAE Vol. 35 (1): January-February 1992.

Liftcells Tensiometer Systems. Suppliers of Industrial Equipment, Australia.
www.Liftcells.com.au.

Loadwise. Instrumentation for the lifting industry, UK. www.loadwise.co.uk.

Miles J. A., Hartsough B. R. and Smith N. (1988): Guy line tension monitors for improved safety and productivity. Proceedings of the International Mountain Logging and Pacific Northwest Skyline Symposium. Portland, Oregon. Dec.1988.

Noble A. and Son Ltd. Lifting Equipment
http://www.nobles.com.au/

Shaw’s Wire Ropes Ltd. Suppliers of “Tensionright” line monitors. http://www.wireropes.co.nz/

Smith, M. (1992a): Remote Tension Monitor for Cable Haulers. LIRO Technical Note TN-5, 1992. Logging Industry Research Organisation, New Zealand.

Smith M. (1992b) : "Remote Tension Monitoring for Cable Haulers". LIRO Report Vol 17, No. 23. Logging Industry Research Organisation, New Zealand.

Tuor, B., Palmer, D. and McMahon, S. (1998): Clamping Carriages and Skyline Tensions. LIRO Report Vol. 23 No. 29, 1998.

Visser, R. M., McMahon, M., Evanson, T. and Palmer, W. (1999): Improving Cable Extraction Efficiency. LIRO Report Vol. 24 No. 16, 1999. Logging Industry Research Organisation, New Zealand.

Wenger, K. F. (1984): Forestry Handbook, 2nd Edition, Society of American Foresters.

WorkSafeBC (2006): Cable Yarding Systems Handbook. WorkSafe British Columbia. Revised 2006. Workers Compensation Board of B.C.