HARVESTING TECHNICAL NOTE

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Constructex Wire Rope: Initial Trials

Summary

Motorised grapple carriages provide benefits in both safety and productivity. However, the need to operate a live skyline and the additional weight of the grapple carriage can impact negatively on the working life of the skyline through frequent high loading cycles. In selecting the type of wire rope for skyline logging applications there is a compromise in balancing resistance to bending fatigue and abrasion resistance. Newer rope designs, while more expensive to purchase, are more flexible, while retaining high strength and wear characteristics. They provide a real alternative to increase the working life of the skyline significantly. This study investigated a number of high performance wire rope alternatives. Constructex wire rope was chosen for testing as it has characteristics designed to increase flexibility without losing strength. This report provides interim results of the initial trials using Constructex wire rope with motorised grapple carriages.

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INTRODUCTION

During cable logging, the wire ropes used are subjected to severe conditions which affect the service life of the rope (Garland *et al.* 2003). The overall goal in selecting a wire rope is to ensure it is fit-for-purpose. The risk of sudden failure should be minimised by identifying the greatest risks to the rope, such as bending, abrasion or crushing. In selecting the best type of wire rope for a given application, two compelling factors that govern this decision are abrasion resistance, and resistance to bending fatigue. Striking the correct balance with respect to these two important characteristics is critical for the service life of the wire rope. For example, it is known that high lead logging is very abrasive, with ropes often being in contact with the ground, while running skylines will suffer bending fatigue relatively quickly.

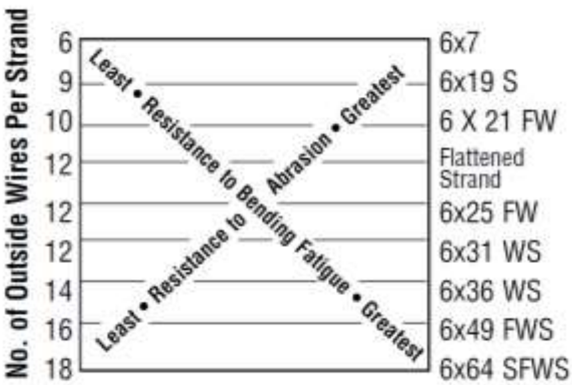

Figure 1: The "X-Chart" demonstrates the inverse relationship between fatigue and abrasion resistance in wire ropes (Hanes Wire Rope Supply).

A graphical presentation of the comparison of qualities for commonly used rope construction types is given by the X-chart (Figure 1).

The chart can help when selecting a rope for a given purpose. The mid-point of the X shows an even balance between abrasion resistance and resistance to bending fatigue. Reading up or down along either side of the chart shows the inverse relationship as one quality increases and the other decreases.

In New Zealand, the wire rope most commonly used for skylines in these applications has been 28-mm swaged 6X26 Warrington Seale (WS) strand construction. WS strand construction has three layers of wires; a Seale style outer layer for abrasion resistance with a Warrington style inner layer for bending resistance. For the standard wire rope range, this choice is logical because it provides a good balance between flexibility, abrasion and fatigue resistance.

As motorised grapple carriages have become more popular in New Zealand several loggers employing these carriages have reported reduced service life of their skylines in comparison to other carriages and rigging configurations. This is reportedly due to the number of wire breaks, resulting in the skyline not meeting safety code requirements and having to be replaced (Ewers & Pratt, pers. comm. 2015).

When using a motorised grapple carriage, the skyline is raised and lowered each cycle to facilitate picking up the stems. Raising and lowering of the skyline each cycle accelerates the wear of the skyline and can reduce the service life of the wire rope by around 40%

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compared to a fixed (i.e. standing) skyline (WorkSafeBC, 2006).

Motorised grapple carriages can weigh in excess of two tonnes and the skyline may be raised and lowered several times in a given cycle to facilitate grappling the log. Therefore the conditions to which the skyline is subjected can be expected to be much more severe than those experienced with other rigging and carriage configurations. The evidence of greater skyline wear suggests that the skyline is subjected to greater bending fatigue. Using swaged rope provides greater crush resistance (which is a known problem with live skyline operations), but also decreases rope flexibility.

It is likely that a number of rope types may be suitable for motorised grapple carriage applications, and therefore it is necessary to assess the cost-benefit of investing in a higher quality rope. While cost is normally readily ascertained through the suppliers, few studies have quantified the benefit of improved rope types.

As part of the FFR Cable Rigging Efficiency project, the primary goal of this study was to trial a new type of wire rope designed to reduce bending fatigue common to all wire ropes used in motorised grapple carriage operations.

ALTERNATIVE ROPE OPTIONS

There are a number of high performance wire rope types that are specially designed for extended service and economic performance in particularly demanding situations. Wire rope manufacturers make a number of these different wire rope options available in logging applications, including Dyform, plastic filled valley rope (PFV), plastic impregnated (PI) rope such as Dyform 8PI, and Constructex®.

Dyform and PFV ropes have been available for decades and were previously trialled in New Zealand logging applications, most of which showed favourable results (Shearer 1982; Simpson 1983; Simpson 1984).

Dyforming is a process where a strand produced from round wires is passed through a die or rollers to squeeze the steel and compact the wires (Figure 2). The process increases the metallic area, like swaging, but creates a smoother contact surface between strands and wires within strands. These ropes have similar crush resistance and abrasion resistance to traditional swaged ropes but are known to have improved resistance to bending fatigue due to the contact surfaces between wires (Simpson 1983).

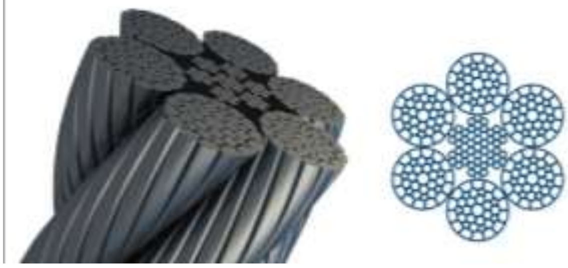

Figure 2: Example of dyform wire rope marketed as Dyform 6 (courtesy of Cookes)

Plastic filled valley (PFV) ropes have thermo-plastic infused around the core and the individual strands (Figure 3). When closed, the plastic fills the valleys between the strands and the core, which effectively lubricates and minimises the internal friction. PFV ropes have exceptional resistance to bending fatigue compared to swaged ropes due to the plastic minimising contact stress between strands and wires (Shearer 1982; Simpson 1984).

Figure 3: Example of PFV wire rope marketed by Cookes as Brifill (courtesy of Cookes)

Another rope option is Dyform 8PI, an eight-strand rope that has been plastic impregnated (PI). The core is coated with thermo-plastic and then the strands are closed around the core (Figure 4).

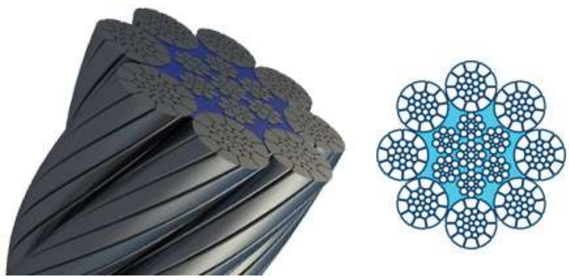

Figure 4: Dyform 8PI wire rope with plastic impregnated (PI) core (courtesy of Cookes)

This rope construction combines the bending fatigue resistant characteristics of dyforming and PFV along with more wires (eight strands) resulting in a rope with exceptional flexibility and fatigue life. Similar ropes have been in use in European cable yarding applications for skylines operating self-propelled carriages (e.g. Teufelberger brand).

Dyform 8PI was considered due to superior resistance to bending fatigue and known applications overseas. In an earlier study however, Shearer (1982) raised concerns over possible difficulties in splicing and attaching fittings due to the plastic fill and the eight-strand construction of the rope which is not common in the logging industry.

Constructex® rope is a special 6-strand swaged design with a smooth surface for high strength, improved wear and crush resistance and better spooling. It is typically used for heavy duty applications requiring maximum resistance to scrubbing, crushing and abrasion. Constructex rope is made of alternating strand constructions (24-wire and 40-wire strands) around a flexible core of three 7-wire strands (Figure 5).

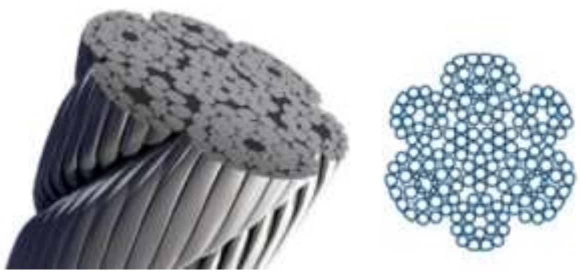

Figure 5: Constructex wire rope now marketed by Cookes as Dura Swage (courtesy of Cookes)

Constructex is believed to have greater resistance to bending fatigue than 6X26 WS, due to its unique parallel closed wire strand core (WSC). In the parallel closing process the WSC and the six outer strands are closed in one operation and lightly swaged to post-form the rope and give the strands a triangular shape. This results in a parallel (regular) lay of strands against the core. Parallel lay improves the contact surface between wires, which reduces internal stress resulting in greater bending fatigue life. Compacting increases strength and resistance to crushing. The smooth outside surface enhances abrasion and scrubbing resistance. Constructex can provide $1^{1}/_{2}$ to 2 times the service life of other wire ropes in severely abusive applications (Hanes, 2015).

Given that the primary goal was to trial a new wire rope to reduce bending fatigue, the Constructex wire rope was chosen. One of the main factors was cost; Constructex was considerably cheaper than a Dyform 8PI in comparison with swaged rope (133% and 253%, respectively). The price of Constructex during the trial (Dec 2015) was $17.78/metre with the potential for the price to decrease with greater demand for the product across the logging industry.

STUDY METHOD

Two lengths of 600m of Constructex wire rope were ordered from overseas, and the final swaging process was completed at Cookes' factory in Auckland. Two cable logging crews purchased and installed the wire ropes, each on Madill 171 yarders that ran primarily motorised grapple carriages. Both crews agreed to provide records of how many months their previous wire rope had been in service in addition to how many tonnes of wood was extracted during that period. This provided a benchmark for comparing the service life of the new rope.

Upon installation, the rope was inspected and measured with electronic callipers for reference diameters in accordance with ISO standard 4309:2010 (Cranes-Wire ropes-Care and maintenance, sections and discard). The reason for this step was that the diameter of each rope was not exactly the same as the nominal diameter (i.e. 28-mm 6x26 WS Swaged rope is often delivered at 28.6mm diameter). The ISO standard assessed the decrease relative to the rope's original measured diameter.

The following ISO severity ratings were used during the inspection, based on the unique properties of Constructex, and should not be used to assess other classifications of wire ropes:

Decrease in diameter (expressed as % of nominal diameter):

- 20% = slight (3.5 < 4.5% decrease)
- 40% = medium (4.5 < 5.5% decrease)
- 60% = high (5.5 < 6.5% decrease)
- 80% = very high (6.5 < 7.5% decrease)
- 100% = discard (>7.5% decrease)

Number of broken wires over 6 and 30 times the nominal diameter (d):

- 25% = slight (3 in 6d or 6 in 30d)
- 50% = medium (6 in 6d or 13 in 30d)
- 100% = discard (12 in 6d or 26 in 30d)

External corrosion:

- 0% = superficial (surface oxidation, can be wiped clean)
- 60% = high (wire surface rough to touch)
- 100% = discard (wire surface heavily pitted and slack wires)

The combined severity rating of each of these modes of deterioration was defined as:

- 40-60% = safe to continue
- 80% = inspect more frequently
- 100% = discard.

Every two months the rope was visually inspected at several points along the operating span of the skyline for deterioration due to wire breaks and corrosion, and the diameter was measured (Figure 6).

Figure 6: Example of inspection points along skyline span

The severity of each of these modes of deterioration as well as their combined severity was noted with each inspection date. These inspections were to be repeated until the ropes were removed from service.

RESULTS TO DATE

Crew One

The first crew installed the new wire rope in December 2015 and to date has used the rope for more than six months. Their previous skyline lasted nine months until it was removed from service due to excessive wire breaks in a section of rope that feeds on and off the drum to mid-span.

Inspections of the new Constructex rope for the first four months of service showed no significant deterioration by any mode. However, there was a 2.6% decrease in diameter in the worst section of wire rope (considered 'slight' by ISO standards) and some minor surface rust on an unused section on the drum (considered 'negligible' by ISO standards).

After six months of continual use the rope started to show some signs of wear. Diameter continued to decrease and was 3.6% less in the worst section inspected, which was considered 'slight' and carried a severity rating of 20%. Fatigue from bending was assessed to have a severity rating of 17% due to two broken wires within one 'six times the rope diameter' segment (Figure 7).

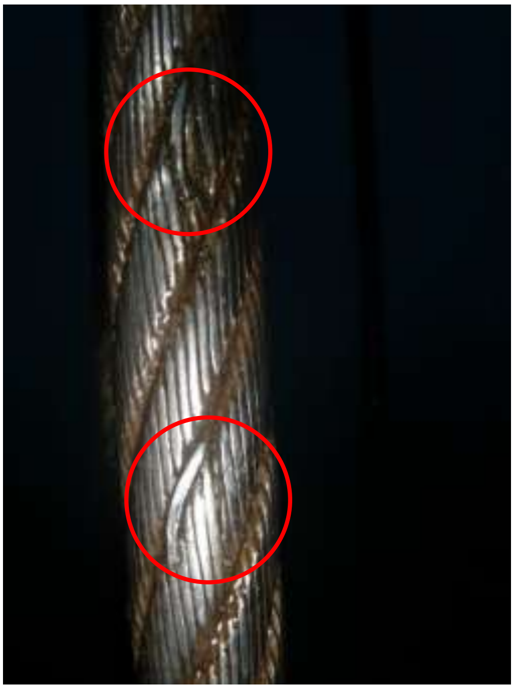

Figure 7: Example of broken wires found during inspection after 6 months of use

These wire breaks were located where a portion of the rope was spooling on and off the drum. The crew was aware of wire breaks in this location and associated the damage with cross-over points when spooling (Figure 8). Cross-over points are considered to be areas where accelerated wear by ISO standards is experienced.

The crew has experienced similar damage with other ropes resulting from cross-over points. Despite the severity due to fatigue from bending and reduction in

diameter, the combined severity rating was still relatively low (37%) and is considered at the lower end of the combined severity scale (40-60% = safe to continue, 80% = inspect more frequently, 100% = discard).

Figure 8: Example of cross-over points when spooling multiple layers onto drums.

Crew Two

The second crew installed their rope in March 2016 and used the rope for approximately one month until it had to be removed from service, due to severe mechanical damage. An error made during operation caused rope wrap between the mainline and skyline which was pulled through a sheave, cutting the skyline. It had been noted by other operators of these carriages that this can happen, and has happened, to other ropes in the past, regardless of their type or construction.

DISCUSSION

Both logging crews addressed several advantages and disadvantages with the new wire rope:

Advantages:

- Spools better on to drum (less damage due to cross over zones and seats itself in well)
- Reduced crushing due to multi-layer spooling (old rope would flatten and not reform, new rope reforms when re-tensioned and appears to be more flexible).

Disadvantages:

- More difficult to eye splice as strands want to unravel when trying to tuck (most likely a result of the parallel closed core).
- Unsure of whether or not an end/butt splice would be feasible

CONCLUSION

To date, the logging crews have been very pleased with the rope's performance. The first crew was surprised how long the rope has been in service and the minimal amount of wear. This crew also received some training from the manufacturer on splicing techniques, and with proper tools and a clamping device they should overcome most of their splicing issues. The manufacturer is also considering workshop testing the rope to determine whether a butt splice would be feasible.

The second crew had similar positive feedback on the rope before it was damaged and have pre-ordered another rope which they hope to install as soon as possible to re-engage in the trial study.

The manufacturer has stated that due to interest in the trials several more Constructex ropes have been ordered from overseas and these will now be marketed under the new name "Dura Swage" for the forestry sector.

This project is ongoing and inspections of the wire rope will continue until it is removed from service. Cookes will also provide test results from their UK testing centre to compare fatigue from bending by testing 6X26 WS swaged and Dura Swage ropes until destruction. Upon completion of this study the combined information will be documented in a final report which will include a summary of the trials and a cost benefit analysis of the new wire rope.

ACKNOWLEDGEMENTS

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REFERENCES

Bridon (2015). "Bridon Wire Rope Crane Catalog." Retrieved 4th June 2015, from http://bridon.co.nz/uploads/catalogues/crane-v6.pdf.

Ewers, D. and A. Pratt (2015). Wire Rope Wear. Personal communication.

Garland, J.J., J. Sessions, S Pilkerton, J. Hartter. 2003. Synthetic rope to replace wire rope in mountain logging operations. Austro 2013: High tech forest operaions for mountainous terrain, held October 5-9th, 2003, Sshlaegl, Austria. 9p.

Hanes (2015). Wire Rope. Buffalo, New York, Hanes Supply Inc.: 24. From: http://www.hanessupply.com/content/pdfs/wirerope101.pdf

Shearer, B. (1982) PFV wire rope. LIRA Technical Release 4(1): Logging Industry Research Association, Rotorua, New Zealand.

Simpson, J.W. (1983). Dyform wire rope trials. LIRA Report Vol 8(2). Logging Industry Research Association, Rotorua, New Zealand.

Simpson, J.W. (1984). PFV wire rope trials. LIRA Report Voll 9(6). Logging Industry Research Association, Rotorua, New Zealand.

WorkSafeBC (2006). Cable Yarding Systems Handbook. Workers' Compensation Board of British Columbia. Vancouver, British Columbia, Canada.

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