HARVESTING TECHNICAL NOTE

HTN09-01
2016

Development of a Tension Monitoring 'App'

Summary

A tension monitoring computer application (app) has been developed for integration with a tension monitor to display and record the tension in wire ropes used in forest harvesting operations, including both cable yarding and cable-assisted tree felling operations. While tension monitors have been available and in use for a long time, their uptake and active use during harvesting operations for both managing and improving performance has been limited by the usability of the data. When coupled with a tension monitor that is capable of streaming data to the mobile device (smart phone or laptop computer), the operator can review the tension data for any recorded period. The app clearly shows the tension relative to safe working load, and a built-in calculator provides an indicator of overall performance in terms of proportion of operating time at given tension levels. In addition to monitoring and improving safe operating practices, the app should also be useful in helping to train new machine operators, to assess the effect of different operating practices on overall tension loading, and to document rope wear. It is recommended that tension monitors should be installed in cable logging operations for safety reasons, and integrating this app into operational use should significantly improve the usefulness of tension data collected.

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INTRODUCTION

Tension monitors have been available in forestry harvesting applications for more than 20 years (Smith 1992; Hartsough 1993). While most new cable-assisted felling machines have built-in tension monitors (Schaare *et al.* 2016), as do nearly all European-built cable yarders, it is estimated that less than a quarter of New Zealand cable yarders have tension monitors fitted. Even when they are installed, few are used to keep track of performance or manage operational efficiency (Evanson 2009; Harrill 2016), as most are installed simply as an overloading warning device.

One probable reason for the low uptake and active use of tension monitors is that the output presented to the operator is typically a small digital reading on a visual display screen, or an audible overload alarm. In all cable logging operations the tension of operating ropes changes rapidly and typical peaks will occur within a very short time period (tenths of one second), and the whole shock load can pass through the cable system in less than one second (Harrill 2014). High tensions and large shock loads typically coincide with the work phases of breakout and inhaul across the mid-span of the skyline. This occurs at a time when the operator is fully engaged with machine operation and unlikely to be able to actively monitor the tension readout in the cab.

Some new tension monitoring systems do provide the mechanism to capture and present tension data. One example is the new tension monitor available from Logpro Ltd in Rotorua, (www.logpro.co.nz/tension-monitor/), which has a built-in computer and automatically stores tension files that can be downloaded through a Wi-Fi connection. An advantage of the Wi-Fi connection is that the tension data is available for other crew members to view (such as the contractor, foreman or Health and Safety representative). This can be done outside the operator's cab using a login to the software on their smart phone or tablet.

Another example of a new tension monitoring system is the ACDAT system from Active Equipment (www.activeequipment.co.nz). This system captures and displays operating information on a small screen in the operator's cab, including mainline distance, terrain information and skyline and guy line tension alarms (when fitted as an option). With the ACDAT system tension can readily be downloaded with a USB flash drive and the data reviewed in a spreadsheet.

As part of the Future Forests Research programme, two projects have been initiated to monitor operating tensions of cable-assist operations and yarding operations to optimise their performance. The need was recognised to develop a user-friendly interface or computer application (app) that can present cable tension information in a way that allows the operator and contractor to not only review what is happening, but also assess previously recorded data. This tension monitoring app has been designed specifically for use in all aspects of forest cable logging operations – operating ropes, guy ropes and cable-assist winch ropes.

DESIGN CONSIDERATIONS

Numerical sampling & refresh rate

The tension values presented on the display or stored for future analyses should be accurate, but also useful and manageable. The electronics used in load cells easily allow 1000 measures per second (1000 Hertz frequency) to be taken and recorded. However, for an operator viewing the tension in real time, and for minimising the amount of data to be stored, the lowest rate that still provides accurate information is desirable.

The question that needed to be answered was “What is the lowest acceptable data rate?” The typical shock load peaks in operating cables are known to occur at a frequency of about $^{1}/_{10}$ of one second (Visser 1998; Harrill 2014). Working with existing data sets, the effect of averaging the data at 0.2, 0.5, 1, and 2 seconds’ frequency was reviewed.

Figure 1 clearly shows that while both 0.2 sec and 0.5 sec frequencies still accurately reflect the absolute values and trends, 1 and 2 second frequencies distort the signal. As such, a data capture rate of 0.5 sec was considered appropriate, especially when considering the display screen refresh rate where operators can be overwhelmed when the digital number display changes more than twice per second.

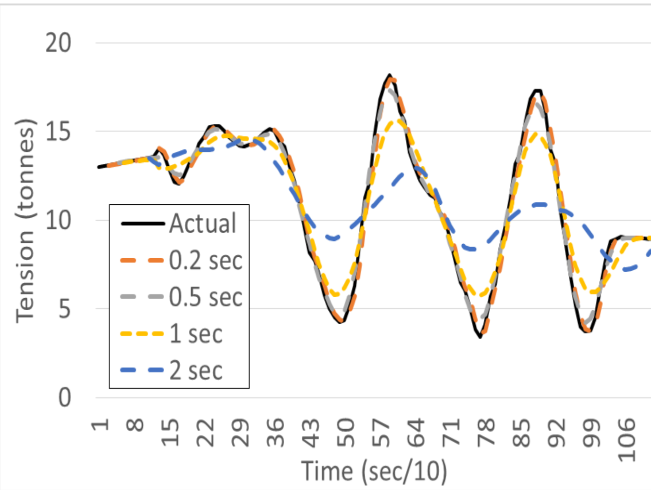

Figure 1: The effect of averaging the tension values.

The Chart

Given the dynamic nature of operating rope tensions, providing a single tension value is often of limited use to anyone looking to understand what tension loads the machine has experienced. Charting the tension over time is a logical step. However, the absolute tension value is also of limited use without putting it into the context of the breaking load of the wire rope.

The minimum breaking load represents the published upper limit as found in the wire rope catalogues, and is different for each diameter and type. In forestry the approved design factor (‘factor of safety’) is defined to ensure that a working rope will not break during operation, and this is referred to as the Safe Working Load (SWL). There are however three relative values that are of interest in terms of managing rope tension:

<u>Elastic Limit:</u>
The elastic limit (sometimes also referred to as the plastic limit) is defined as a single load that permanently deforms the wire rope. So while it does not break, the rope stretches without going back to its original condition and the steel itself will strain-harden. This makes the rope more brittle and unsuitable for further use as a working rope. While the exact elastic limit is different for each rope type, it is typically about 65% of the minimum breaking load. As such, this is an upper limit that should never be exceeded during operations.

<u>Endurance limit:</u>
All metal working componentry wears out over time, and wire rope is no different. For wire rope a common concept is the number of cycles to failure. That is, when bending a rope over a sheave under a specific load it is possible to calculate, or at least estimate, the number of cycles before that rope breaks. It has been established that this relationship is exponential in that at very low loads relative to the minimum breaking load the rope will ‘never’ break. For example wire ropes used in bridges and lift elevators are designed like this where the overall loading is less than 10% of the minimum breaking load.

In forestry applications higher loading is accepted as it provides a balance between the practicality of working with the smallest dimension rope and an acceptable rate of wear (for cost reasons). For working rope applications, a realistic value for the endurance limit is 50%. That is, if the rope tension never exceeds 50% of minimum breaking load, the rope will last for a very long time (but not forever!).

<u>Safe Working Load (SWL):</u>
A safety factor of three is commonly used in logging to determine the working load limit for a standing or running line. This factor is very common in most countries that have safety rules for cable logging

HARVESTING TECHNICAL NOTE

operations (e.g. Oregon OSHA 2006; WorkSafe BC 2013). In New Zealand this 'factor of safety' of three, or 33% of the rated breaking load of the wire rope has been defined in the Approved Code of Practice (ACOP 2012): "All load-bearing wire ropes used in forest harvesting work shall be used so that the safe working load of one third of the minimum breaking strength of the rope is not exceeded."

This factor of safety is expected to be used for the design of cable logging and cable-assisted felling systems, since it allows for some shock loading given that rope tensions are unpredictable, and in any event are often not measured during normal operations. Of interest is that in the new European forestry wire rope standard, the benefit of continuous tension monitoring is recognised in that yarders with integrated tension monitors need only work with a factor of safety of 2.5, or 40% of minimum breaking load.

METHOD OF USE

For the purpose of this app, the user enters the rated minimum breaking load of the wire rope, and the app sets up the chart with coloured zones (Figure 2): Green – below SWL; Blue – above SWL but below Endurance limit; Orange – above Endurance but below Elastic limit. This makes it easy to interpret the data. Not showing is Red – above the Elastic limit, which will show only if tension values reach that high.

Using the touch interface, the data screen can be expanded to show more data, zoomed to focus in on less data, or swiped to show previously recorded data. Two buttons provide default settings: the 'Recent Activity' will bring the screen back to the current data flow, and 'All Activity' will zoom out to show all of the data recorded for that time period (e.g. for each day or each file).

Figure 3 shows what an All Activity screen might look like, and the user can readily identify the peaks for each cycle, and count the number of times SWL has been exceeded.

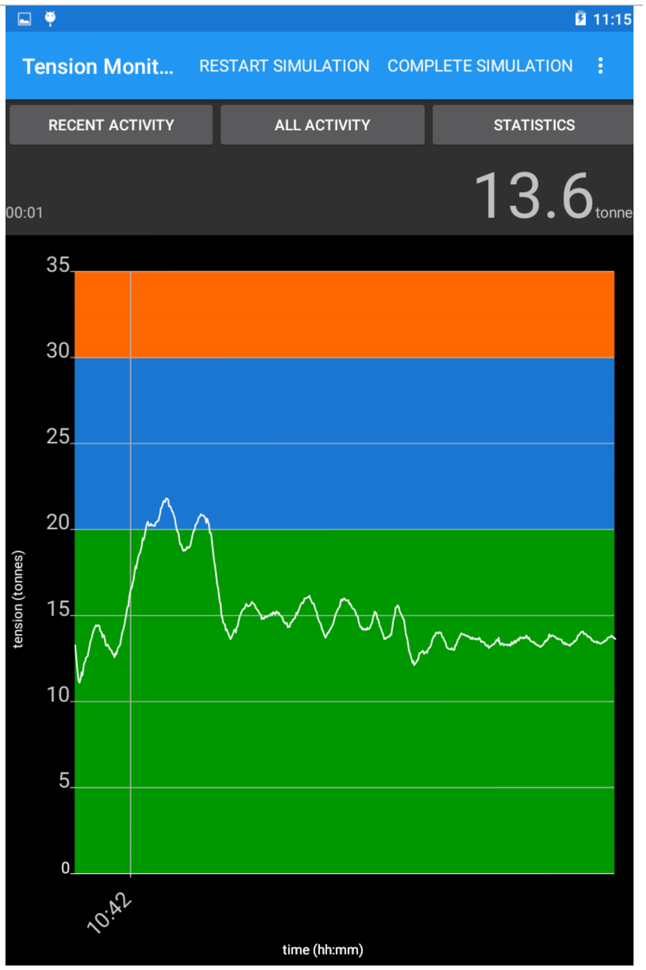

Figure 2: Data screen of app showing current tension data in coloured zones that relate to the minimum breaking load.

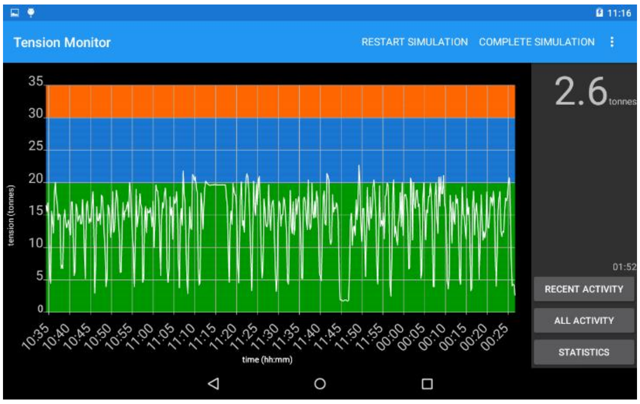

Figure 3: All Activity screen of the app showing the tension data for a longer period of time.

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DISCUSSION: DATA EVALUATION AND USE

The dynamic nature of the tension data has been recognised, especially that sometimes shock loads may exceed SWL. It has been proposed that it is more important to identify the percentage of time that the operation has exceeded SWL, rather than just whether SWL is exceeded or not (Schaare, Harrill and Visser, 2016). This measure would be more representative of the system as a whole and would allow a clearer comparison between different operating techniques, or performance between different operators or systems being used.

The app features a 'Statistics' button to display summary statistics of the tension data (Figure 4). The app calculates the proportion of operating time the tension is in each defined tension zone for the data that is present on the screen (as defined by the user). This feature can be used to assess overall performance of an operator, or to display the effect of any operating changes that have been made (such as a change in rigging configuration). A quick comparison can then be made to highlight the difference between the two periods of interest. The app gives the user the ability to swipe and scroll backward in time to evaluate what has just happened.

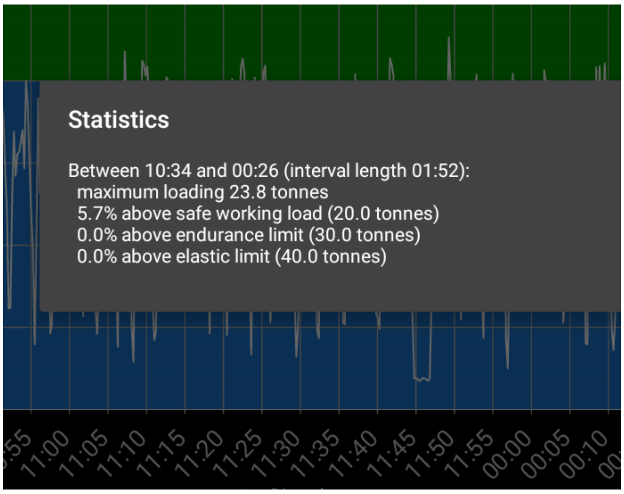

Figure 4. Screenshot showing sample statistics of the tension data in each zone.

The statistics can also be used as guidance for monitoring rope wear and replacement. For example:

1) If any event causes the tension to exceed the plastic limit it should trigger a full inspection of the rope as well as all the connectors. The event should also be recorded as a near miss so that action can be taken to avoid such mishaps in the future.

2) If tensions greater than the endurance limit are recorded on multiple occasions then a review of operating procedures should be instigated to avoid further occurrences or incidents of poor practice.

There are many more uses for the app and the information that it provides, such as operator training, comparing operators, and productivity assessment and improvement. Some of these uses are explored in a further FFR project (Harrill, 2016).

It is recommended that tension monitors should be installed in all cable logging operations for safety reasons, and that this app is integrated into operational use of tension monitoring.

CONCLUSION

A tension monitoring app has been developed to help facilitate the uptake and improved use of tension monitors in both cable logging and cable-assist harvesting operations. The app features have been designed to make it most useful to the operators.

The app has been presented to a selection of both yarder operators and machine manufacturers. The feedback has been very positive in terms of both the clarity of the data presented and the usefulness of the features, especially the ability to swipe and scroll backward in time to evaluate what just happened, and the ability to document rope wear.

Clearly the next step is to release the app to the forest industry and integrate its use into cable yarding and cable-assist systems for the improvement of both safety and productivity.

ACKNOWLEDGEMENTS

Amy Martin is a final year Software Engineering student at the University of Canterbury. The authors would like to acknowledge her supervisor in the Department of Computer Science and Software Engineering, Dr Austen Rainer, for his assistance in development of the app.

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