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REMOTE TENSION MONITORING FOR CABLE HAULERS

Mark Smith

ABSTRACT

Understanding the dynamics of the wire rope system on a hauler has up until now been the field of cable mechanics' scientists, or an operator's intuition and feeling for the system. This Report describes a prototype remote tension monitoring system and outlines some of the benefits from measuring and displaying real time line tensions for hauler operators, contractors and planners.

INTRODUCTION

Cable logging systems have the potential to generate enormous tension in all of their component lines, whether moving or static. Even with careful setup, operating circumstances may result in lines being overstressed. While over tensioning may not lead to immediate rope failure, it does result in reduced rope working life. The results are, without exception, expensive and, in the case of rope failure, very dangerous.

Figure 1 - Madill 171 fitted with LIRO tension monitoring system

The two means of avoiding line overloads are careful planning and actual tension monitoring. Planning involves analysis and prediction of rope tensions prior to operations commencing. For operational purposes, it becomes necessary to actually monitor rope tensions.

The technology for monitoring rope tensions in their working environment has been under review and development for many years. Various devices have been proposed but few have advanced past the prototype stage. The demanding working environment has, to date, been a major obstacle.

Taking advantage of refined technology, LIRO and Actronic New Zealand Limited have recently produced a new Remote Tension Monitoring (RTM) system. The system was developed for use by hauler operators in a working situation. The features of this unit, its potential applications and proposed further developments are described in this Report.

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THE PROTOTYPE RTM SYSTEM

One of the simplest methods of measuring line tensions in a cable logging operation is to install an "in-line" load cell. However, there are drawbacks with using in-line load cells which can make them inconvenient in operational situations and they have often been considered a weak link in the system (Miles, Hartsough and Smith, 1988). By comparison, the LIRO system mounts externally on the rope removing the possibility of introducing a weak link into the line (Figure 2).

Figure 2 - LIRO dynamometer fitted to the guyline of a Dispatch hauler

Some overseas systems in the past have been considered impractical as operational tools because of the "hard wiring" (Miles et al, 1988). A distinguishing feature of the LIRO system is its ability to transmit data over distances of 600m by radio, removing the need for any hard wiring.

The load cells and radio transmitters are battery powered. Therefore, power conservation is important. If the change in tension is relatively small the dynamometers will transmit the tension only once every ten seconds. When the change in tension is more rapid the system sends data signals more frequently, at approximately one second intervals.

The maximum data transmission rate of approximately one signal per second was chosen because operators would have difficulty responding to the information any faster. A similar rate was recommended for a system built in the United States due to operator reaction time (Miles et al, 1988).

The LIRO system has a built-in computer which handles all the radio signal analysis and calculation functions for the display unit. The unit has a user friendly interface to enter various parameters. The system allows five different rope sizes to be used; 19, 22, 26, 28, and 32 mm. The display can be easily changed to show various rope tensions in different screen positions, or with different labels (Figure 3).

Other features include the ability to check the radio signal strengths being received from the dynamometers and the battery condition. The system also has the capability to allow for a reduced breaking strength due to rope wear or damage.

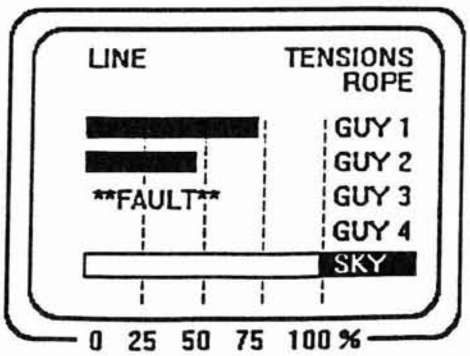

Figure 3 - Display screen showing horizontal moving bars representing line tension as a percentage of safe working load

POTENTIAL APPLICATIONS OF TENSION INFORMATION

There are several important applications for the RTM and these are discussed within the following categories:

Safety

Although rope failures are not a common source of injury in New Zealand, when they do occur the injuries are often serious. Examination of records from the New Zealand Logging Industry Accident Reporting Scheme suggests that five out of thirty-two rope related accidents may have been prevented if the hauler operator had been aware of the rope tensions. Part of the recent increase in the proportion of accidents occurring in hauler operations, as opposed to other logging accidents in New Zealand, has been attributed to the number of hauler crews starting operations in recent years (Parker, 1992).

Hauler crews have employed a deliberate "weak link" in high-lead systems by using lighter line for strops. In contrast, a skyline can be easily overloaded without overloading the strops or dropline.

Two trends are evident in the evolution of cable logging systems; an increasing level of sophistication in the functions performed by the operating lines and a reduction in the number of guylines to decrease the set-up time. Both trends represent greater application for tension monitors in ensuring safe operation of the system.

Guyline Setup and Monitoring

Guyline tensions can be checked by hand while a substantial static load is applied to the main rope or skyline. With different guyline lengths and angles, it is difficult to estimate the required pre-tension in each guyline to ensure the set-up remains balanced under dynamic loading and between rope shifts. Operators have been shown to be unable to identify which guylines have the highest tension until they are given feedback on their actual loadings (Miles and Hartsough, 1987).

For these reasons, it is beneficial to monitor guyline tensions, especially during the inhaul phase, when the most severe dynamic loads are experienced and to use the information to adjust the guylines accordingly.

Guyline pre-tension also affects a tower's load capacity. Over tensioned or under tensioned guylines can affect tower deflection and increase stresses in the tower when the skyline is loaded (Mann and Pyles, 1988). A balanced and correctly tensioned guyline set-up would avoid placing undue stress on the tower.

Stump anchors may work loose during operation and result in a decrease in guyline tension. This could be immediately noticed by an operator using a tension monitor. Stump failure, however, is usually rapid and would probably happen too rapidly for an operator to react and slacken the lines (Liley, 1985). If an empirical relationship for stump strength versus diameter exists for the area, a tension monitor will enable the operator to check that the tension in the guyline is not exceeding the safe working load of the stump. The benefit of preventing stump anchor failure, by monitoring line tensions, is very large when the consequence could be a hauler overturn and injury of workers (Pyles, Mann and Anderson, 1988).

A study of fifteen spar overturns was made in British Columbia revealing that poor guyline rigging was the cause of thirteen of those fifteen accidents (Ewart, 1978). Operating a hauler within the allowable line limits should improve safety and drastically reduce the incidence of tower overturns or failures (Jorgensen, Carson and Reutebuch, 1978).

Careful attention to the guyline rigging and the presence of a tension monitoring system would provide an operator with early warning of a poorly rigged guyline system. Displayed tension information keeps the operator informed of the line tensions in relation to their safe working load (SWL).

Skyline Spotting Brake Check

Care must be taken to ensure that the skyline spotting brake will slip before the SWL of the skyline is exceeded. This will also avoid overloading the brake assembly (Ewart, 1978).

A tension monitor can be used to check that the skyline spotting brake is slipping at the correct skyline tension. This may be important with older or modified machinery where ropes or other equipment differ from the original manufacturer's specifications.

The results from a check carried out on a Madill 046 hauler show the maximum skyline spotting brake air pressure setting for a given wrap on the skyline drum (Table 1).

Table 1 - Madill 046 skyline spotting brake calibration (35mm swaged skyline)

Drum Wrap Layer	Distance down from flange (cm)	Drum Torque at SWL (kNm)	Maximum Brake Air Pressure kPa (p.s.i.)
First	29	103	331 (48)
Second	25	116	386 (56)
Third	22	127	442 (64)
Fourth	18	141	690 (100)
Fifth	15	151	690 (100)

Safe Engine Output To Avoid Overloading Skyline

A calibration similar to the skyline brake check can be carried out to find out the engine r.p.m. which causes the skyline line tension to reach SWL. These tests and calculations are easily performed and can be graphed or put into tables for quick reference by the operator (Table 2).

Table 2 - Madill 046 engine output to avoid overloading the skyline

Drum Wrap Layer	Distance down flange (cm)	Maximum Engine speed (rpm)
First	29	1500
Second	25	1500
Third	22	1600
Fourth	18	1700
Fifth	15	1700

Training

There is an increasing demand for new hauler operators as hauler numbers expand in New Zealand. Hauler operators currently rely on experience and a feel for their machine for operating it within its limits. A tension monitor would assist those operators lacking experience by providing information to complement their feel for the machine and increase their learning rate and understanding of the system. Tension monitoring systems developed in the past have been considered excellent training tools (Miles and Hartsough, 1987).

Tension monitoring systems can be used to provide "real time" feedback of tension data to demonstrate the effect of the operators actions on the system. For example; demonstrating how different skyline tensions can affect the breakout forces in other lines.

Tension data collected before and after training sessions with an operator may be useful in evaluating the effectiveness of training.

New System Evaluation

Not only new operators need training. Experienced operators can find themselves in an unfamiliar situation if they use different rigging systems or machines. A tension monitor could be a useful reassurance to those operators going through a period of adjustment to the new conditions. The learning period for crews working with new systems could therefore be reduced using a monitoring system.

If intermediate supports or tail spars are used in New Zealand in the future, there may be a need to monitor guylines on those spar trees remotely. Work conducted in the United States suggests that guyline pre-tension is an important factor in safe operation of spar trees (Pyles, Ammeson and Mann, 1988). A spar tree failure would cause long operating delays while a replacement was re-rigged.

Wire Rope Damage

In the New Zealand logging industry, wire rope is considered to have a SWL of one-third its breaking strength. A wire rope will behave elastically up to approximately 60% of its breaking strength. If the load exceeds 60% of the breaking strain, the rope will be permanently stretched and weakened. Repeated shock loading to approximately 50% of the rope's breaking strength (ie. the endurance limit), will eventually cause damage to, or failure of, the rope.

Whenever a rope passes over a sheave or drum the outer wires in the strands are subjected to bending stress. This stress is compounded by the load in the line, especially shock loads.

Ropes which have been in use for some time can be expected to have a reduced breaking strength due to wear and fatigue. By operating the ropes consistently below the SWL, shock overloads will be less likely to exceed the endurance limit. Tension monitoring has the potential to avoid repeated overloading of the ropes and extend their life.

The costs of a line breakage should not be overlooked. Lost revenue, production, operating cost and safety are all important factors when considering the consequences of a failure. In an economic evaluation, the probabilities and costs of failures in different ropes could be weighed against the cost of owning and operating a tension monitor. The design safety factor for cable logging payload calculations, i.e. a SWL of 33% of breaking strength, has been argued on economic grounds (Sessions, Pyles and Mann, 1985). If the operator knows the line tensions with accuracy, it may be possible to increase payloads with confidence in some situations, reducing the reliance on conservative safety factors.

Productivity

An important benefit of tension monitoring for contractors is the potential for increased productivity from optimising payloads. One of the most important factors affecting productivity is the average load volume or drag size. If larger payloads can be put on the skyline and the operator can monitor the line tensions, productivity can be increased (Jorgensen, Carson, and Reutebuch, 1978).

The optimum combination of cycle time and payload will depend on the payload being large enough so that production per cycle is high. However, excessive payloads will cause too much time to be spent breaking out and possibly line overloads. The relationship between payload and cable tension has been investigated in past studies (Inoue and Umeda, 1988; Bloomberg and Liley, 1985). Display of tensions would help the operator and breakerouts optimise payloads.

A hauler's engine capacity, drive train, interlocking and braking ability may make it impractical to tension lines to the SWL and could result in predicted payloads not being attainable (Mann, 1985; Hartsough, Miles and Burk, 1987; Hartsough, Miles and Darling, 1987).

Feedback to the breakerouts would be necessary to optimise payloads using a RTM system. Radio contact with the hauler operator or direct feedback of tension information to the breakerouts are two possible ways of achieving this.

Work Study Applications

The day-to-day operational benefits that can accrue from knowing payloads and the corresponding line tensions cannot be realised without consistent use of tension monitoring equipment permanently installed on the hauler (Pyles, Mann and Anderson, 1988). Hauler operators and contractors may find more uses and practical solutions to their problems with use of tension monitoring equipment. Some possible uses of tension information specifically for logging planners and contractors are given below.

Data Collection

Data collected automatically by a remote tension monitor could be used to form a data base of information about payloads and line tensions. This information would be useful for both the planner and the contractor when planning and estimating payloads for a new block. Automatically collected tension data could be used as an audit trail in the event of an accident in the same way an aircraft flight recorder or "black box" is used.

Verification of Predicted Payloads

Skyline payload analysis programs used for planning rely on cable mechanics theory. Predicted payloads are not usually checked against actual loads obtained during logging. Discrepancies between predicted and actual payloads might show trends allowing corrections to the software used for predictions or adjustment of existing production targets. Recording line tensions during logging will also allow dynamic load factors to be incorporated into skyline analysis programs and provide better payload estimates for planning (Mann and Pyles, 1988).

Time Studies

Line tension data can be used as a research tool for time studies on haulers. If this data is recorded automatically, it can substitute a work study person and make a time study less expensive. When the tension information is combined with other automatically recorded information, such as haul distance, then it becomes a more powerful tool (Sperisen, 1988).

Regular recording of cycle times extracted from tension data could be used as a production measure or incentive for manpower productivity. Simple and immediate feedback on crew performance could be used for target setting by the contractor or individual crew members themselves.

The tension information could be used like a service recorder to record hours of work, down time, etc. Long term trends may show up which suggest ways for the contractor to improve the work system.

FUTURE DEVELOPMENTS

The LIRO remote tension monitor was developed as a prototype of a future commercial model. Further improvements to future models will be made from experience testing the system.

Monitoring the tension in moving lines will be the next major development in the application of load cell technology to cable logging. When the mainline is the limiting line an understanding of the forces in it is essential for optimising payloads and improving productivity.

Improved load cell technology or indirect measurement of tension could see better systems developed. One potential system, using a laser to indirectly measure cable tension, was experimented with in the United States (Hartsough and Kroneberger, 1989).

Future research will investigate the applications of tension monitoring systems and quantify the benefits. The technology will need to be improved in such a manner as to capitalise on those benefits. A suitable commercially built and fitted system should be readily developed based on the applications. Retro-fitted kits could be added to existing machines and hauler manufacturers could incorporate tension monitoring systems into their designs.

CONCLUSIONS

Remote tension monitors have considerable potential to improve many aspects of cable hauler operation. The technology required to monitor rope tensions in real time and provide feedback to the operator has been developed by LIRO. It is now a matter of developing methods to usefully apply the technology in operational situations.

At this stage, the major justification from the contractor's point of view for the capital investment required for a tension monitoring system comes from the benefits of increased safety, training and productivity. However, many of these potential benefits are difficult to quantify without long term research information.

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For further information, contact:

LOGGING INDUSTRY RESEARCH ORGANISATION
P.O. Box 147,
ROTORUA, NEW ZEALAND.

Fax: 0 7 346-2886 Telephone: 0 7 348-7168