AN ABSTRACT OF THE PAPER OF

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Title: Applications for Synthetic Rope in Logging

Abstract approved

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Steel wire rope is used for many logging applications. This material has served the logging industry well in terms of strength, durability, and longevity. Steel wire rope is difficult to use because of properties that make it stiff, heavy, and unyielding. These same properties cause fatigue, exhaustion, and may contribute to worker injuries.

Our research placed synthetic rope samples in the hands of selected loggers to try out alternatives to steel wire rope. Few studies have addressed the use of synthetic rope for logging applications. Initial trials with cooperating logging contractors showed positive ergonomics and logging productivity efficiencies. The logging industry is slow to change; so, not all of these initial trials were accepted. Designed research of synthetic rope in logging is needed to determine when synthetic rope is a suitable replacement for steel wire rope.

Synthetic rope has the potential to replace steel wire rope for many logging applications. In our trials, we assessed static line applications (guylines, intermediate support lines, tree

straps, and snap guylines) and running line applications for yarding and ground-based logging systems. Our running line applications using synthetic rope included two skidder / crawler tractor winching trials, a Boman Mark IV carriage trial, and a Koller K300 mainline trial.

Static line applications such as guylines, intermediate support lines, tree straps, and snap guylines are acceptable replacements of steel wire rope with synthetic rope. Loggers were more likely to try additional applications once they used synthetic rope as tree straps and were confident of its strength. Cost was an initial drawback for most logging contractors. Additional research is needed to determine damage, replacement, and wear criteria for synthetic rope in logging applications.

Running line applications showed positive results in the skidder / crawler winching trials with faster cycle times and increased efficiencies for using synthetic rope. The Koller K300 mainline trials also produced positive results as a running line. The Boman Mark IV internal drum carriage trial showed no significant differences between steel wire rope and synthetic rope. We believe designed research is necessary to evaluate carriage applications with synthetic rope.

Future studies for static line applications should include guyline taglines, skyline taglines, haywire (rigging line) replacement, and various other applications. Putting synthetic rope into the hands of users will help identify valuable applications where synthetic rope has merit. Future studies for running lines should focus on designed trials to adequately observe the effects of synthetic rope in specific applications such as side-hill lateral yarding, uphill lateral pulling in winching trials, and other difficult logging conditions.

Preliminary results show synthetic rope is a good candidate for the replacement of steel wire rope in selected logging applications. More research is needed to determine damage, replacement, and wear criteria for all applications of synthetic rope in logging.

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Applications for Synthetic Rope in Logging

by
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I understand that my paper will become part of the permanent collection of the Oregon State University Forest Engineering Department. My signature below authorizes release of my paper to any reader upon request.

Jared M. Leonard

Jared M. Leonard, Author

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CONTRIBUTION OF AUTHORS

Mr. Steve Pilkerton assisted with the collection and interpretation of data throughout the project. Mr. Steve Pilkerton also assisted in reviewing Chapter Two. Dr. Glen Murphy and Dr. Kevin Boston were involved with the interpretation and analysis of data for Chapter Three.

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CHAPTER 1

INTRODUCTION AND RESEARCH ORGANIZATION

Steel wire rope is used for many logging applications. However, steel wire rope is heavy, awkward, and stiff. These properties contribute to making logging one of the most difficult jobs known. The difficult nature of work with steel wire rope can cause fatigue and may contribute to worker injuries.

In Oregon, disability claims according to the Workers Compensation Claims Report of 2001 totaled 452 claims within the logging sector. A total of 34% of these claims came from chokersetters, rigging slingers, and hooktenders. Within this occupation group, 32% of such claims were related to overexertion and falls (OR-Department of Consumer and Business Services, 2001).

An injury from wire rope that is common but not easily quantified comes from jaggers or broken strands of steel wire rope that can cause puncture wounds and can lead to infection and irritation. Additionally, logging injury statistics for the fingers totaled 4.6% of the body parts affected by injury (OR-Department of Consumer and Business Services, 2001).

Synthetic rope has the potential to produce substantial economic and ergonomic gains. Synthetic rope is an alternative to steel wire rope. According to Pilkerton et al. (2001), synthetic rope, Amsteel Blue[1], manufactured by Samson Rope Technologies of Ferndale, Washington meets the physical property requirements and is suitable for use in logging applications. We decided to use only this type of rope for all of our exploratory trials even though other products or rope types might be suitable.

To better understand how synthetic rope may work as a replacement for steel wire rope, we placed synthetic rope samples with selected logging contractors.

The specific objectives for this project were:

- Place synthetic rope samples with cooperating logging operators to observe how they used the new material.
- Evaluate synthetic rope performance for static rigging applications.
- Evaluate running line applications for a yarder mainline.
- Evaluate running line applications on an internal drum carriage dropline.
- Evaluate two ground based skidder / crawler tractor winching applications.
- Evaluate and quantify logging contractor views on synthetic rope using a survey.
- Determine, to the extent possible, the feasibility and economic potentials of applications for synthetic rope in logging.

These trials were conducted during the summer of 2002 and the first half of 2003. Each logging contractor was given sufficient length and diameter rope to test these applications. After an initial trial period, researchers visited the logging contractors to evaluate synthetic rope for the specific application. Some operators were studied both

[1] Mention of trade names does not constitute an endorsement by Oregon State University

with steel wire rope and synthetic rope applications. Problems, potentials, and subjective evaluations were collected for analysis.

Chapter two includes research trials involving synthetic rope for static rigging applications in cable logging. Guylines, intermediate support lines, tree straps, and snap guylines are evaluated and experiences summarized. Conclusions are summarized for the trials.

Chapter three describes research trials focused on winching applications for synthetic rope in logging. This chapter covers both ground based skidding applications with wheel skidders and crawler tractors under different operating circumstances. A skyline carriage winching application is assessed using synthetic rope on an internal drum winch. A yarder mainline winching application is evaluated under western Oregon operating conditions. Pilot trials including limited time studies were conducted to determine the utility of synthetic rope for these applications and to design future studies using synthetic rope. Conclusions and recommendations are summarized for the trials.

Chapter four includes a survey that was conducted with eight logging contractors to determine experiences, collect observations, and assess uses of synthetic rope for these applications. A list of logging cooperators is included in Appendix one. The survey transcript and survey questionnaire are found in Appendices three and four.

Chapter five includes recommendations and future research with winching trials.

Chapter six includes general conclusions for the project and outlines future research needs related to synthetic rope use for logging.

This report format is based on two papers. Chapter two is a conference paper included in the Council on Forest Engineering (COFE) 26th annual meeting proceedings held in Bar Harbor, Maine, September 7-10th, 2003. Chapter three is intended for submission to a scientific journal.

References are specific to each chapter and included at the end of chapters two and three. General project references are included at the end of this report.

Appendices cover logging cooperators with the project, specific time elements for each of the running line trials, the survey transcript used, and the survey questionnaire.

CHAPTER 2

EVALUATION OF SYNTHETIC ROPE FOR STATIC RIGGING APPLICATIONS IN CABLE LOGGING

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Paper presented at the 26th annual meeting of the
Council on Forest Engineering, Bar Harbor, Maine

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INTRODUCTION

Steel wire rope is used for many logging applications. This material has served the forest industry well in terms of strength, durability, and longevity. Steel wire rope is difficult to use because of properties which make it stiff, heavy, and unyielding. These properties cause fatigue, exhaustion, and may contribute to worker injuries.

An alternative to steel wire rope is synthetic rope. Garland et al. (2002) showed the characteristics and properties of synthetic rope make it a suitable candidate for use in logging applications. However, further research is necessary.

The objectives of this study were to replace steel wire rope with synthetic rope for selected logging contractors to reduce workloads, improve efficiencies with cable logging, and determine the extent to which synthetic rope is suitable for use in static rigging applications. Longer term use by loggers was seen as an important means to assess the rope and find new problems and opportunities.

Few studies have addressed the use of synthetic rope for static rigging applications in cable logging. Takumi (1998) assessed the use of synthetic rope as guylines for a mobile tower yarder. Technora synthetic rope in this study was found to have sufficient strength and fatigue life to be used as guylines. However, it was difficult to estimate the fatigue life and strength loss from the appearance of the rope. The study also found the synthetic rope lost strength more rapidly than steel wire rope. The study used the number of cycles over a sheave as the basis for residual strength measurements.

Synthetic rope in our tests is Amsteel Blue[2] and is made from ultra high molecular weight polyethylene (UHMWPE Dyneema fibers) which makes it lightweight yet strong (The American Group, 1997). On average, synthetic rope weighs 1/9th that of the same nominal diameter steel wire rope. The high strength to weight ratio makes synthetic rope a suitable candidate for static rigging applications commonly used in cable logging.

The Amsteel Blue rope is constructed of synthetic fibers woven into a 12-strand braid. The twelve strand braid yields the maximum strength to weight ratio and is comparable in strength to steel wire rope, yet floats. This type of rope has a high flex-fatigue life and wear resistance compared to other products made from UHMWPE.

Cost is a factor to consider when choosing materials for static rigging applications. On average, synthetic rope costs 2-4 times as much as similar diameter steel wire rope. Logging contractors are cost sensitive and the cost for synthetic materials must return added benefits that exceed the additional cost.

Static rigging typically requires line lengths of 100 to 250 feet for various rigging conditions. Typically, these lines are used to guy tailtrees at the far end of yarding corridors. Coiled lines are often carried to these locations where they are rigged. Intermediate supports also require rigging for both the intermediate support jack line and the guylines which stabilize the support tree.

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[2] Amsteel Blue is a product of Samson Rope Technologies, Ferndale, WA. www.samsonrope.com. Mention of trade names does not constitute an endorsement by Oregon State University.

Tree straps are used to hang blocks and other rigging in trees. The size of these tree straps is determined by the size of the skyline on the yarder. Typically a steel wire rope with a 7/8 inch diameter tree strap or larger would be required to meet the current Oregon Occupational Health and Safety Administration (OR-OSHA) safety code (www.orosha.org/standards/div_7.htm). Steel wire rope tree straps are difficult to bend around a small tree and keep positioned while securing blocks, shackles, and other rigging hardware. This presents a safety hazard for tree climbers.

APPLICATIONS EVALUATED

Our research focused on the use of synthetic rope for four static rigging applications. The applications were:

- Guylines
- Intermediate support lines
- Tree straps
- Snap guylines

Five logging contractors were supplied test samples of synthetic rope for one or more of the rigging components listed. The longest trial lasted from 1999 to early 2003 (3.25 years); however, the same contractor had used one or more types of synthetic rope for 5.5 years. Other trials with the remaining four contractors are still underway.

GUYLINES

The need for lightweight, flexible guylines is recognized in the logging industry. A steel wire rope guyline of 5/8 inch diameter, 150 feet in length weighs approximately 111 pounds. A similar guyline made of synthetic rope may weigh only 18 pounds. The purpose of a guyline is to support or stabilize a spar tree, tail tree, intermediate support tree, machinery or equipment.

Figure 1. Synthetic rope guylines and strap supporting tail tree block

Loggers carry guylines up and down steep, treacherous hillsides to the location of intermediate support trees or to the end of a yarding corridor where they are used on tail trees. Garland et al. (2002) found that travel times for carrying a 150-foot coil of steel wire rope and coil of synthetic rope for 150 feet downhill did not differ significantly; however, carrying steel wire rope uphill took twice as long as carrying synthetic rope uphill. Although the downhill carrying times did not differ significantly, there was an obvious safety advantage of carrying an object that weighed 18 pounds versus one that weighed 111 pounds down a 45 percent slope.

Figure 2. Guyline wraps on a tree and shackled to another tree

Ten guylines were placed into service during the study period. Two 5/8 inch diameter, 125-foot guylines were given to each logging contractor for use in their cable logging operation. The guylines were used on a Diamond D210 swing yarder, John Deere 330LC yoader[3], Koller K501 yarder, and a Howe-Line Mark IV yarder. This variety of conditions and range of logging equipment commonly found in the Pacific Northwest provided a good basis for evaluation.

Guylines were configured with two buried spliced eyes, one on each end of the guyline. Buried spliced eyes yield the ultimate breaking strength of the rope (specified for testing) and are the simplest end termination to create. Typically guylines are shackled back to themselves when they are rigged in a tree. This allows a simple and fast connection method (Figure 1.) The other end is brought down to a tree or stump where it is terminated. Often, several wraps are made on the anchor tree or stump to take up excess length and the guyline itself terminated at another tree or stump in close proximity. Once wraps are made (Figure 2), the guyline is terminated with another shackle. The termination process involves making wraps on the termination tree or stump, bringing the line back over itself and wrapping the line until the slack is completely removed. The line is then shackled back to itself (Figure 3). This method is a suitable technique for terminating synthetic rope guylines.

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[3] A yoader is an excavator-based cable yarder with no guylines to stabilize the machine itself.

Guylines must be tightened to provide stability. Synthetic rope guylines may be tightened sufficiently by hand because it is possible to pull the guyline tight without much sag (deflection) in the guyline. It is not always possible to pull the sag out of steel wire rope guylines to properly position the tree for loading. Another tightening process can be accomplished using the twister strap that involves using a stick or similar object to reduce the overall length of the guyline. This method yields residual strengths of approximately 80 percent of double the catalogue breaking strength. Yet another approach is to use a rigging chain and come-a-long (ratcheting pulling device) commonly used to tighten steel guylines. A way to employ the rigging chain approach is to use the grab hook end (Figure 4) instead of the open hook end of the chain. Once the guyline is tightened, the rigging chain can be removed from the guyline with ease.

Figure 3. Termination of guyline with shackle

Figure 4. Use of a rigging chain for tightening a synthetic guyline

Testing of the residual strength of synthetic guylines was performed in a laboratory setting at Oregon State University. The guylines tested included both the 3.25-year use and the 5.5-year use ropes. The average residual strength for the 3.25-year use guylines (9/16 inch Amsteel Blue) was 15,341 pounds. The average residual strength of the 5.5-

year use guylines (9/16 inch Amsteel Gray) was 16,720 pounds. The 3.25-year use ropes had a percent yield of 38% of the catalogue minimum breaking strength. The 5.5-year use ropes had a percent yield of 60% of the catalogue minimum breaking strength.

A potential benefit during rigging trees with synthetic rope may be the use of rappelling devices (used for rock climbing) to descend from the tree. Although not recommended in the current Oregon Division 7 Forest Activities Code, the use of a rappelling device such as a figure-eight descender could reduce fatigue and rigging times by allowing the rigger to rappel down the tree instead of climbing down.

INTERMEDIATE SUPPORT LINES

Four trials were conducted to evaluate the use of synthetic intermediate support lines. The lengths tested included one 250-foot and three 125-foot intermediate support lines of 5/8 inch diameter synthetic rope. The most common rigging configuration consisted of attaching the intermediate support jack to the intermediate support line and terminating the support line at a stump or tree (Figure 5). Tightening and attaching the intermediate support line is similar to tightening a guyline.

Figure 5. Synthetic intermediate support line

A proper notch is needed when attaching synthetic rope to a tree or stump. If the saw cuts made to form the notch do not match, they produce a recess from the saw kerfs between the horizontal cut and the beveled cut. When a load is placed on the line, rope will "bite" into the recessed kerfs. This makes removal of the line difficult when heavy loading occurs during yarding. Matching the horizontal and bevel cuts of the notch avoids this problem.

TREE STRAPS

Three trials were conducted to evaluate the use of synthetic tree straps. One tree strap was configured in an endless loop design while the other two were configured as a single strap with a buried spliced eye at each end. The endless loop design was preferred by one logging contractor because the splice used to construct the endless loop actually increases the stiffness of the tree strap. The single strap with spliced eyes is a more common configuration found in the Pacific Northwest.

Figure 6. Synthetic tree strap, endless loop design

Tree straps are wrapped up in the tree above a branch whorl to aid in stability. A block is then attached directly to the tree strap or with the aid of a shackle (Figure 6). The tree strap may be configured in a basket design where the end is fed through the opposite end of the sling (endless loop), or the single strap with eyes are brought together and attached to the block. The tree straps used in this study were 7/8 inch diameter Amsteel Blue™. The specific advantages of these two designs were not the focus of this study; however, the following observations came from the trials:

1) When constructing an endless loop design, the length of the strap when stretched should be no shorter than 6 feet. Any length shorter than this is unpractical for most tree sizes (14 inches – 26 inches) found in the Pacific Northwest.
2) The single straps with eyes were 20 feet long. The extra length of this design allowed the strap to be wrapped multiple times around the tree providing more stability than with a shorter strap.

Flexibility is a factor to consider when selecting a tree strap. Because steel wire rope is quite stiff, it is difficult to wrap around a tree, hold in position, and attach rigging. Synthetic rope can be wrapped around a tree quite easily and results in less rigging time. Garland et al. (2002) found that the time to rig an intermediate support tree was on average two minutes longer with steel wire rope than synthetic rope. This time difference was attributed to the increased difficulty (i.e. properties) of steel wire rope. The steel wire rope used was 5/8 inch diameter, considerably more flexible than 7/8 inch steel wire rope. Significant gains can be achieved with synthetic rope to replace the larger steel tree straps commonly used.

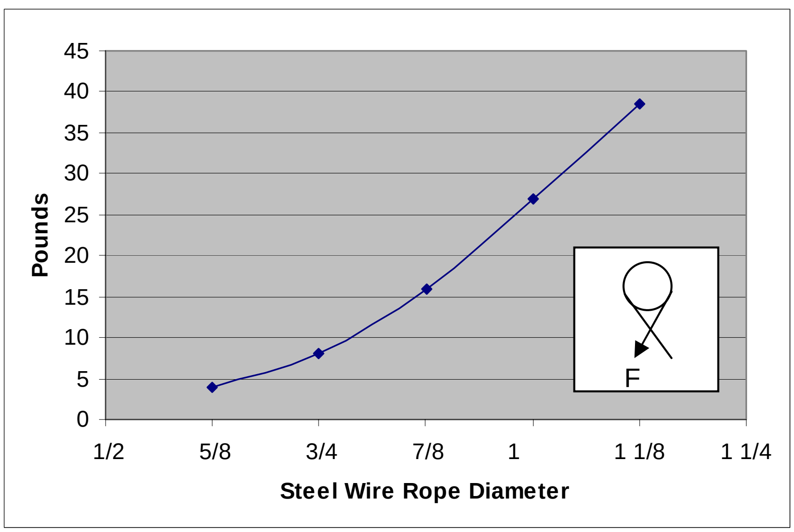

Figure 7. Force required to bend various diameter steel wire rope tree straps around a 13" log

To better understand how the properties of steel wire rope affect rigging effort, tests were performed to measure the force required to bring different sizes of steel wire rope around a simulated tree configuration. In contrast, the force required to bring synthetic rope together was assumed to be nearly zero. The test was conducted using a 13 inch diameter tree. A scale measured the force required to bring the eyes around the tree to a point where a shackle could be attached (see inset, Figure 7). The force required to bring the two eyes together for various steel wire rope diameters increases as rope diameter increases (Figure 7). The effect of tree size was not assessed. However, larger trees require heavier steel wire rope straps while smaller trees increase the "spring tension" to bend the rope around the tree.

SNAP GUYLINES

One snap guyline was evaluated during this study period. The purpose of a snap guyline is to prevent the yarder tower from overturning backwards in case of skyline or mainline failure. The snap guyline is simply a safety mechanism for some yarder towers. The snap guyline was used on a Koller K300 yarder and was 5/8 inch diameter by 100 feet. The snap guyline was shackled to the top of the tower, and terminated at a stump or tree in the direction of the yarding corridor. It is usually only necessary to tension the snap guyline by hand. The light weight and ease of use might increase use of a synthetic snap guyline for logging crews.

DISCUSSION

This study evaluated the use of synthetic rope to replace steel wire rope in static cable logging applications. The assessment of each application was descriptive and based on observations made by researchers and logging contractors.

Synthetic rope guylines proved to be suitable for replacing steel wire rope guylines. The reduction in weight, ease of use, and simplicity in rigging are all benefits. The average breaking strength of two used 9/16 inch Amsteel Blue guylines was 38 percent yield (15,341 pounds) of catalogue minimum breaking strength. These guylines would have been suitable for use on skylines up to 5/8 inch diameter. The ropes tested for residual strength were of normal wear that is specified by the rope inspection and retirement guidelines set forth by The American Group (1997). Further research is needed to establish retirement guidelines for used synthetic rope guylines.

Visual inspection of the used guylines did not indicate any severed or cut strands. It is important to acknowledge that most logging equipment has sharp metal edges which can damage synthetic rope and reduce residual strength. Eliminating the contact with sharp metal edges will provide a longer service life from synthetic rope.

A technique used but not evaluated during the trials is the potential use of rappelling devices for descending trees. This approach should be further evaluated to determine the feasibility and implications for safety code inclusion.

Synthetic intermediate support lines have distinct advantages over steel wire rope. With steel wire rope lines, initial raising of the support jack often requires a come-a-long and can be a tedious process to raise the support jack to an acceptable height. With the reduction in weight, synthetic rope can be raised much easier and often without the aid of a come-a-long thus saving time and increasing efficiency. Wire rope uses u-bolt clips or Crosby clamps to secure guylines or intermediate support lines, while synthetic rope offers a reduction in the time spent rigging and de-rigging because a shackle is the only terminal connection. Other quick terminations may be on the horizon for synthetic rope as research continues.

Synthetic rope tree straps were immediately acceptable as replacement for steel wire rope straps. Once logging contractors felt comfortable with the strength and durability of synthetic rope in this application, they were more likely to try other applications such as guylines or intermediate support lines of synthetic rope. A pre-conceived notion about the strength properties was the largest factor of concern for loggers during these trials. The basket design and single strap with eyes were the only tree strap configurations studied during these trials.

Synthetic snap guylines are safety measures for cable logging and are easy and simple to use. One logging contractor studied was more likely to use synthetic rope for this application due to the lighter weight of material and ease of rigging.

CONCLUSIONS

This preliminary evaluation of synthetic rope for use in static rigging applications shows synthetic rope to be suitable for replacing steel wire rope in these applications studied. Further analysis to determine damage and wear criteria is suggested to identify replacement criteria for ropes in various applications.

The initial cost of the synthetic rope is a drawback for most logging contractors. However, the benefits of using synthetic rope for static rigging applications in cable logging seem to outweigh this concern. Benefits such as decreased rigging times, reduced workloads due to lighter weight materials, ease of use, and a potential to increase production are factors to consider when assessing the cost-benefit ratio between steel wire rope and synthetic rope.

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CHAPTER 3

EVALUATION OF SYNTHETIC ROPE FOR WINCHING APPLICATIONS IN LOGGING

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INTRODUCTION

Steel wire rope is used for a variety of logging applications. The durability, strength, and longevity of steel wire rope have allowed this material to be a suitable candidate for logging applications. However, the properties of steel wire rope including weight, stiffness, and bending characteristics create problems during use. These properties have contributed to a variety of injuries to woods workers.

Steel wire rope is used in large quantities for cable logging. Applications like those of crawler tractors and wheeled skidders have long used steel wire rope for winch lines. However, the weight of steel wire rope often limits how far workers can pull line. This occurs during ground-based winching applications or in lateral yarding for skyline systems.

Synthetic rope is an alternative to steel wire rope. Garland et al. (2002) showed the characteristics and properties of synthetic rope make it suitable for use in logging. However, the suitability of synthetic rope for logging needs to be evaluated to determine which applications are suitable for replacing steel wire ropes.

Some synthetic rope can be made from ultra high molecular weight polyethylene (UHMWPE) which makes it lightweight. This same material is used to make plastic fuel containers, crane sheaves, and even plastic wrap used in the food industry. Variations of molecular bonds allow this material to have different strength properties for specific applications. Because it is a type of plastic, synthetic rope weighs on average $1/9^{th}$ that of similar diameter steel wire rope, yet is as strong (diameter for diameter).

PRIOR RESEARCH

Few studies have addressed the use of synthetic rope for logging applications. Early trials with synthetic rope indicate that skidding operations show substantial opportunities not only in ergonomics, but in production efficiencies as well.

Lapointe (2000) found that synthetic rope is easy to use for winching applications on skidders. These trials also indicated maximum winching distance could be increased up to three times that of steel wire rope. However, these results were not widely implemented because the synthetic rope used was not durable. The end termination of the winch line also had problems due to insufficient strength and durability.

Golsse (1996) tested two different types of synthetic rope for a wheeled skidder winching application. One application used synthetic rope made from Spectra®, as a suitable candidate for replacement of steel wire rope. Golsse (1996) noted that longer winching distances were possible and could be an advantage especially on sensitive sites. Winching distance was increased up to three times that of steel wire rope, without a significant increase in operator fatigue. However, Spectra® synthetic rope was expensive and did not respond well to cuts caused by mainline sliders (connector for chokers).

Kevlar™ was used during a study by the Forest Engineering Research Institute of Canada (FERIC) for skidding with an all terrain vehicle (ATV), (Dunnigan 1993). This trial proved synthetic rope was a viable alternative to steel wire rope. Dunnigan (1993) also noted Kevlar™ was safer than nylon or polyester ropes because of reduced backlash or whipping that occurs when the rope breaks. This trial especially noted synthetic rope was vulnerable to sharp metal edges and cuts.

CURRENT RESEARCH

The properties of some synthetic ropes are suitable for logging (Garland, et al. 2002). To assess whether synthetic rope has a place in logging, industry trials were conducted to determine where synthetic rope could replace steel wire rope. We provided selected logging contractors with synthetic lines for two skidder / crawler winches, a motorized slackpulling carriage, and a yarder mainline.

Trials were conducted during 2002 and early 2003 to evaluate synthetic rope in four applications:

- Caterpillar D6 crawler tractor winching trial
- John Deere 650G crawler tractor winching trial
- Boman Mark IV internal drum carriage trial
- Koller K300 mainline trial

Amsteel Blue[4], a durable rope made from Ultra High Molecular Weight Polyethylene (UHMWPE) with good resistance to cutting was selected as the rope to try because of its properties. This product is highly regarded in the off-shore, marine, and fishing industries for its durability and strength properties (Roberts, et al. 2002). For comparison purposes, we elected to use a single type of rope for our trials even though other products or rope types might be equally suitable.

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[4] Amsteel Blue is a product of Samson Rope Technologies, Ferndale, Washington. www.samsonrope.com. Mention of trade names does not constitute an endorsement by Oregon State University.

The objectives of our research were:

- To place synthetic rope samples with selected logging operators to see how they would use and evaluate the synthetic rope.
- To assess feasibility of synthetic rope to replace steel wire rope in specific applications.
- To compare and measure differences in time for use of synthetic and wire rope.
- To assess productivity and economic implications of synthetic rope uses.
- To survey participating logging operators about their subjective evaluations of using synthetic rope.
- To identify problems, opportunities, and research needs for using synthetic rope in logging.

While we did monitor synthetic rope damage and failures in our study, we did not attempt to assess wear and deterioration of synthetic rope from use.

METHODS

Time studies were used to collect data for each of the trials. The detailed time study data was used to help evaluate the differences between steel wire and synthetic rope for the same application.

The detailed time study data recorded the time and conditions required for each turn (a sequence of activities used to bring logs or trees to the landing). Each turn was broken into time elements, delay times broken out by type, and independent variables recorded.

The data was used to generate regression equations and predict elements in a turn. Handheld stopwatches were used to record the time elements. Delay times were not included in the regression equations but are summarized separately in tables. Time study data was collected in centi-minutes (cmin) which is 1/100th of a minute.

The research team also took subjective comments and responded to issues and problems arising from the operator's use of the rope. Rope damage and operating problems were noted during the trials.

In some trials, detailed stand volumes and log volumes were recorded. These volumes were used to summarize differences between the trials and systems. In trials where there was no stand or log volumes obtained, the number of logs per turn was recorded and was used for production analysis.

Site 1 – Caterpillar D6 Crawler Tractor Winching Trial

A logging contractor, Dakom Logging, had been using a Caterpillar D6 crawler tractor and Carco F50 winch. The logging contractor had 7/8 inch swaged steel wire rope for the skidding line. Five 9/16 inch slider style chokers were used. The drum contained approximately 50 feet of steel wire rope. The logger operated the crawler, set his own chokers and unhooked logs during this trial.

This trial focused on the use of the current system with a steel wire rope skidding line followed by the use of a 7/8 inch synthetic rope. A total of 120 feet of synthetic rope replaced the steel wire rope (Figure 8).

Data for this trial was collected on a private ranch near John Day, Oregon in the summer of 2002. The harvest unit was composed primarily of Ponderosa pine (*Pinus ponderosa*) with some Douglas fir (*Pseudotsuga menziesii*) and Western juniper (*Juniperus occidentalis*). Trees were selected to harvest based on the logging contractor's judgment whether the tree was damaged by insects and disease. There were on average 180 trees per acre. The average basal area (BA) was 78 ft^2 for Ponderosa pine. Terrain conditions ranged from rock outcrops to grassy hillsides. Skid roads were constructed when skidding across the slope was necessary.

Figure 8. Synthetic rope winchline with slider style chokers

After an initial trial period, the slider style chokers were replaced with five 9/16 inch pear style chokers and the accompanying toggle. This modification was made because the slider style chokers tended to pinch the mainline and cause delays.

The pear and toggle system uses a series of chokers with a "pear" shaped ring that slides against a "T"-shaped toggle at the end of the skidding line. The synthetic rope was spliced directly to the chain link of the toggle. The pear and toggle system allows chokers to be quickly removed if a hang-up occurs during skidding. The pear ring design also eliminated the pinching action when using the slider chokers. The skidding line was attached to the winch with a B-6 ferrule attached to the synthetic rope with epoxy. For a similar connection, the epoxy end termination pulled out at 30 percent of the breaking strength of the rope.

The objective of this trial was to compare the effect of rope material on the lateral yarding element. Due to limited data collection for this trial, a descriptive approach was used for reporting purposes.

Site 2 – John Deere 650G Series IV Crawler Tractor Winching Trial

The cooperating logging contractor utilized a 1999 John Deere 650G Series IV crawler tractor with a John Deere Series 4000 winch and Young fairlead. The current system used approximately 80 feet of 5/8 inch swaged steel wire rope for the skidding line. Four slider style chokers ½ inch diameter were used. The logger set his own chokers during this trial; however, occasionally the landing chaser would unhook a turn.

Figure 9. Synthetic rope winchline with ring style chokers

This trial compared steel wire rope versus synthetic rope used as a winchline. A total of 120 feet of 5/8 inch synthetic rope replaced the current steel wire rope in this system (Figure 9). Four pear style ½ inch diameter chokers and a toggle replaced the slider style chokers to avoid pinching of the skidding line during the lateral out phase. The end termination was a B-5 ferrule with a splicing technique known as a back splice. The back splice yields approximately 12 – 15% percent of the breaking strength of the rope in similar tests.

Data for this trial was collected on a series of timber sales in early 2003. Initial trials were held on a tree farm owned by the logging contractor, Scoggins Creek Harvesting Corporation. The tree farm is located near McMinnville, Oregon and was a typical Coast Range stand composed primarily of Douglas fir. Stand volume data was not available for this trial; however the silvicultural prescription was a clear cut.

The second timber sale these trials occurred on was located near Gaston, Oregon. The silvicultural prescription for this stand was a clear cut. Both sites contained fertile soils. Ground slopes for both sites ranged from 35-40 percent.

The objective of this trial was to compare steel wire rope with synthetic rope in a crawler tractor winching trial. The effect of rope material on the lateral out element was the focus; however, data was collected to analyze the total turn. A regression analysis used a 0/1 indicator variable for synthetic rope for elements thought to effect the total turn time.

Site 3 – Boman Mark IV Internal Drum Carriage Trial

G & B Logging, a logging contractor from Monmouth, Oregon assisted in the research during this trial. The logger operated a 1974 Madill 071 yarder and 2000 Boman Mark IV internal drum carriage. The Boman carriage was outfitted with 300 feet of 5/8 inch Superpac steel wire rope and contained a load hook for attaching chokers. The logging contractor typically used two to three 9/16 inch chokers with an eye end connection. The owner operated the yarder; another operator used a 2001 Madill 2800B loader with a chaser on the landing. Two loggers set chokers and also performed road changes and rigged trees.

This trial replaced the 5/8 inch Super Pac skidding line with 300 feet of 5/8 inch diameter synthetic rope skidding line (Figure 10). Because the connection to the carriage drum required the use of a ferrule for attachment, a B-4 ferrule was attached to the rope with epoxy.

Figure 10. Synthetic rope on Boman Mark IV internal drum carriage

Data for this trial was collected on the Oregon State University (OSU) McDonald Research Forest during the summer of 2002. The harvest unit was part of a modified seed tree silvicultural prescription leaving 6 trees per acre for wildlife. The McDonald Research Forest is owned by the College of Forestry just north of Corvallis, Oregon in the Coast Range. Conditions during the trial were dry and dusty. Slopes ranged from 5 percent to 50 percent, although some yarding corridors were below 5 percent deflection because of inadequate cable rigging heights. Douglas fir was the primary species harvested. The stand contained 165 trees per acre. Initial basal area was 228 ft^2 and was harvested to a residual basal area of 40 ft^2.

The objective of this trial was to determine the effect of rope material on the lateral out element. A regression analysis used a 0/1 indicator variable for synthetic rope in elements thought to affect the total turn time.

Site 4 – Koller K300 Mainline Trial

The Forest Engineering Department at Oregon State University maintains a student logging crew which performs harvest operations and provides logging experience to the students of the College of Forestry. The Student Logging Crew uses a 1983 Koller K300 yarder mounted on a 1984 Kubota M6950DT tractor as a power source. The Koller SK-1 gravity carriage used with this system passes the mainline through the carriage to the logs. Typically, four 3/8” ring style chokers and toggle are used. A four person logging crew includes: a yarder engineer, skidder operator, and two chokersetters.

Figure 11. Synthetic rope as mainline on Koller K300 yarder

This trial compared steel wire rope mainline (3/8 inch diameter) with a 3/8 inch synthetic rope mainline to evaluate production and time elements. Approximately 1100 feet of steel wire rope was replaced with 1200 feet of synthetic rope (Figure 11).

Data collected during this trial was completed during the summer of 2002. The OSU Student Logging Crew was harvesting a unit on the McDonald-Dunn Research Forest. The primary species was Douglas fir (*Pseudotsuga menziesii*), although some Western

Hemlock (*Tsuga heterophylla*) was present in the stand. The silvicultural prescription was 1-acre patch cuts and thinning from below leaving 120 ft^2 of basal area. Slopes ranged from 10 percent to 70 percent in the harvest unit.

The objective of this trial was to determine the effect of rope material on the lateral out element. However, the total turn time was analyzed to determine if other elements were affected by the rope materials. Two skyline corridors were used to collect data, one for steel wire rope and one for synthetic rope. A 0/1 indicator variable was used for elements to indicate use of synthetic rope.

Operating Elements

Each trial had slightly different time elements of the operating cycle studied. A summary of each trial is listed in Table 1. A more detailed description of each time element can be found in Appendix 2.

Table 1. Summary of time elements for steel wire rope and synthetic rope trials

Element	John Deere 650G	Boman Mark IV	Koller K300
Outhaul	X	X	X
Lat out	X	X	X
Hook	X	X	X
Mount	X		
Lat in		X	X
Car ahead		X	
Winch in	X		
Winch ahead	X		
Crawl ahead	X		
Inhaul	X	X	X
Down		X	X
Unhook	X	X	X
Up		X	X
Decking	X		

DATA ANALYSIS

All statistics were calculated using the S-PLUS statistical package. Plots were constructed to determine linear relationships for each of the three trials.

Multiple linear regression analysis was used to develop models to predict the dependent variables in terms of the independent variables. Variables included in the analysis had to meet $\alpha = 0.05$ significance level. Residuals were examined to determine the presence of outliers and the suitability of the models.

RESULTS FROM TRIALS

Site 1 – Caterpillar D6 Crawler Tractor Winching Trial

Because of interruptions to logging operations and distances to sites, time study data was not available and subjective assessments were made. The results from site 1 indicate that synthetic rope is a good candidate for replacement of steel wire rope for this application. The logging contractor used synthetic rope for eleven months and continued to use synthetic rope after this study period. During that period, the rope broke several times. Damage to the rope from the rocky operating conditions was thought to be the cause of the breakage. The operator reported he also broke steel wire rope under similar conditions. The initial winchline was returned in early 2003 to researchers and an additional 120 feet was long-spliced to the initial line. The initial winchline returned to OSU was 70 feet long, which was 50 feet shorter than when the trial began. The rope contained dirt and debris and had fuzzy strands where abrasion occurred. The winchline was sent back to the contractor for continued use.

SUMMARY

The trial involving the Caterpillar D6 with Carco F-50 winch in eastern Oregon proved to be successful. The logging contractor was initially apprehensive concerning the strength properties of synthetic rope, but performed his own pull test and quickly became aware of the benefits after a short trial period.

Logging conditions in this area often require physically strenuous work for loggers. Lateral winching distances can reach greater than 100 feet in some operating conditions requiring substantial physical exertion to pull winchline. With the aid of synthetic rope, this task can be achieved with less physical exertion (Garland, et al. 2002).

During initial trials, the logger would maneuver the Caterpillar D6 as close to the logs as possible before pulling winchline laterally to the logs. We observed that with use of synthetic rope, the logger modified his operating practices to where he pulled line farther than steel wire rope winchline. These results are similar to those made by Lapointe (2000) and Golsse (1996) where lateral winching distance was increased for synthetic rope winchline.

The modified practice with less machine maneuvering was observed to have some positive benefits causing less soil disturbance and reducing soil compaction. However, once winching distance increases, the angle of the winchline through the stand subjects the winchline to rubbing on trees, residual stand damage, and winching is over rocks and other obstacles.

The logging contractor noted he was able to increase the horizontal angle from fairlead of the winch to access more logs than with steel wire rope. Because increased angles damage steel wire rope by "pig-tailing" (creating spiral rope rather than straight rope), angles from the fairlead must be less than 30 degrees. This pig-tailing can be avoided with synthetic rope because it is not damaged by these increased angles (Figure 12). Log hook times benefit because more logs can be reached with less maneuvering of the skidding machine.

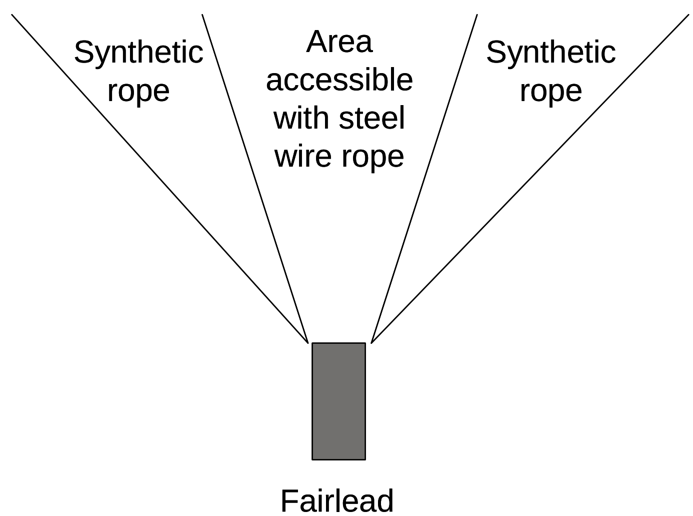

Figure 12. Example increase in horizontal angle from fairlead for synthetic rope compared with steel wire rope

Site 2 – John Deere 650G Series IV Crawler Tractor Winching Trial

The results from site 2 indicate that synthetic rope decreases task time for lateral winchline pulling. Simple linear regression models were constructed for elements where independent variables were recorded. Mean times were recorded for other elements in the cycle. The regression relationships developed are in Table 2.

Outhaul – The outhaul element is related directly to the distance the crawler must travel during a turn. The mean time per cycle was 264 cmin. The mean distance was 735 feet; the minimum was 200 feet and the maximum was 1000 feet.

Table 2. Delay free regression equations[a] for elemental / occurrence[c] model for John Deere 650G winching trials

Element	Relationship	R^2	n
Outhaul	81.83 + 0.36*dist	0.98[b]	92
Lat out	0.83*dist + 7.87*synthetic(0/1) - 0.50*synthetic(0/1)*dist	0.91[b]	62
Hook 1	17.56		90
Mount	17.04		73
Winch In	16.05 + 0.38*dist	0.21	82
Winch/Crawl Ahead	31.15		62
Inhaul	0.38*dist	0.98[b]	89
Unhook	2.76 + 0.18*No. logs	0.16	86
Decking	88.24		54

[a]Units are in cmin (1/100 min), feet
[b]Model was forced through the zero intercept, R^2 values are artificially higher
[c]Of the 92 cycles collected, elements with less than 92 observations must be a pro-rated summation of the elemental regression equations to estimate the total cycle time

Lat out – The mean times differed significantly for the trials using steel wire rope or synthetic rope ($p = 0.006$). The mean time per cycle was 17 cmin. The mean distance was 22 feet with a minimum of 5 feet and a maximum of 60 feet.

Hook 1 – The mean time per cycle was 18 cmin. The minimum was 5 cmin, the maximum was 44 cmin.

Mount – The mean time per cycle was 17 cmin. The minimum was 5 cmin, the maximum was 41 cmin.

Winch in – The mean time per cycle was 28 cmin. The mean distance was 32 feet with a minimum of 7 feet and a maximum of 85 feet.

Winch/Crawl ahead – The mean time per cycle was 31 cmin. The minimum was 7 cmin, the maximum was 145 cmin.

Inhaul – The mean time per cycle was 277 cmin. The mean distance was 725 feet with a minimum of 250 feet and a maximum of 1000 feet.

Unhook – The mean time per cycle was 33 cmin. The mean number of logs was 3.49 with a minimum of 1 log and a maximum of 5 logs.

Decking – The mean time per cycle was 88 cmin. The minimum was 15 cmin, the maximum was 540 cmin.

Delays – The delay times were summarized by type (Table 3). The majority of the delays (23 percent) during the steel trials were related to re-hooking logs. The majority of delays (29 percent) during the synthetic trials were related to talking.

Table 3. Percent of delays by type for John Deere 650G winching trials

Delay Type	Steel	Synthetic
Backspool	1.70%	0.00%
Brush	0.23%	0.13%
Bucking	17.23%	21.16%
Build road	11.30%	7.05%
Choker	2.89%	4.75%
Falling	2.38%	1.25%
Looking for logs	2.39%	0.99%
Pushing tops	3.48%	8.03%
Rehook logs	23.19%	16.92%
Stuck logs	7.23%	4.14%
Talking	16.81%	28.67%
Unknown	9.68%	6.79%
Walking	1.48%	0.11%

SUMMARY

The trial involving the John Deere 650G Series IV crawler tractor lasted 7 months. Initial problems with cutting the synthetic rope from poor operating practices led to early failures. The pear design chokers were replaced with ring chokers because it was thought these contributed to degradation in the synthetic winchline. After using the synthetic winchline with ring chokers, less abrasion was apparent. In total, the synthetic winchline broke 11 times during the trial period.

It is important to note that a change in operating practices was needed to make synthetic rope work in these conditions. The logging operator was willing to give synthetic rope a try, but did not modify his operating practices. The chokers used were too long. Instead of hanging the chokers on the fairlead after unhooking, the operator would winch the winchline into the drum until the chokers were clear of the tracks. This practice caused the toggle to damage the synthetic winchline. After explaining the cause of the damage to the operator, he modified his operating practices eliminating this problem.

Some simple changes in operating practices are required with synthetic rope winchlines. The following are a few observations made during our trials:

- Grinding off all burrs and rough edges from fairlead and rollers is required.
- Grinding off burrs and rough edges from ring chokers is required.
- Avoid instances where the winchline must be pulled around stumps or logs to change winching angle. Seek straight pull when possible.
- Hang chokers on the fairlead instead of winching chokers into drum.

During these trials, the contractor decreased the free-spool tension mechanism to allow the drum to spool more freely during the lateral out element. Synthetic rope does not have the rotational mass of steel wire rope, thus it is not necessary to maintain a tighter tension for proper free-spooling.

Site 3 – Boman Mark IV Internal Drum Carriage Trial

The results from site 3 indicated no significant difference between steel wire rope and synthetic rope. Each element of the cycle was modeled as a separate linear regression and produced an equation to predict the elemental time. The regression relationships developed from the data are in Table 4.

Outhaul – The outhaul element is related directly to the outhaul distance the carriage must travel during a turn. The mean time per cycle was 3 cmin. The mean distance was 377 feet with a minimum of 75 feet and a maximum of 685 feet.

Table 4. Delay free regression equations[a] for elemental / occurrence[b] model for Boman Mark IV internal drum carriage trials

Element	Relationship	R^2	n
Outhaul	25.15 + 0.02*outhaul dist	0.09	248
Lat out	13.32 + 0.64*latout dist	0.37	211
Hook	23.35 - 5.44*preset(0/1)	0.02	238
Lat in	20.93 + 0.49*latin dist	0.21	181
Car Ahead	32.32		50
Inhaul	19.91 + 0.18*inhaul dist	0.34	255
Unhook	3.71 + 3.40*no. logs	0.20	252
Up	11.23		244

[a]Units are in cmin (1/100 min), feet

[b]Of the 255 cycles collected, elements with less than 255 observations must be a pro-rated summation of the elemental regression equations to estimate the total cycle time

Lat out – The lateral out element was not significantly different using steel wire rope or synthetic rope ($p = 0.324$). The mean time per cycle was 37 cmin. The mean distance was 37 feet with a minimum of 10 feet and a maximum of 130 feet.

Hook – The hook time did not differ significantly for the trials using steel wire rope or synthetic rope ($p = 0.220$). The mean time per cycle was 22 cmin. The minimum time per cycle was 3 cmin; the maximum time was 237 cmin.

Lat in – The lateral in times did not differ significantly during this trial ($p = 0.342$). The mean time per cycle was 41 cmin. The mean distance was 38 feet with a minimum of 8 feet and a maximum of 159 feet.

Car ahead – The time to position the carriage was significantly different ($p < 0.0001$) for steel wire rope and synthetic rope. This difference cannot be explained because no independent variables were measured nor had any relation to rope type. The mean time was 32 cmin. The minimum time during a turn was 12 cmin; the maximum was 103 cmin.

Inhaul – The mean time for inhaul was 87 cmin. The mean inhaul distance was 377 feet. The minimum distance was 75 feet; the maximum 685 feet.

Unhook – The unhooking element was directly related to the number of logs per turn. The times for steel wire rope and synthetic rope did not differ significantly ($p = 0.071$). The mean time to unhook was 9 cmin per turn. The average number of logs per turn was 1.56 with a minimum of 1 log and maximum of 4 logs per turn.

Up – The time to winch the load hook up was significantly different for the steel wire rope and synthetic rope trials ($p < 0.0001$). The difference cannot be explained because no independent variables were measured. A difference in the height of the chute was thought to be the source of variation for this element. The mean time for the up element was 11 cmin. The minimum was 4 cmin and the maximum 26 cmin.

Delays – The delay times were summarized by type (Table 5). The majority of the delays (69 percent) during the steel trials were related to operational activities. The majority of delays (85 percent) during the synthetic trials were related to operational activities. Back-spooling was the largest delay during the synthetic trial, comprising 49% of the delays.

Table 5. Percent of delays by type for Boman Mark IV internal drum carriage trials

Delay Type	Steel	Synthetic
Add choker	5%	4%
Backspool	1%	49%
Other	12%	21%
Remove choker	2%	0%
Reposition logs	19%	15%
Talking	5%	5%
Unhook choker	2%	0%
Unknown	38%	2%
Walking	8%	0%
Yarder	8%	4%

SUMMARY

The trial involving the Boman Mark IV internal drum carriage showed no significant difference between materials for any of the operating elements collected.

Synthetic rope used in this trial was also a significant cause of delays. Backspooling on the internal drum was the major delay type due to operating practices.

When steel wire rope is used, the stiffness of the rope is enough to push it out and over the sheave on the carriage and backspooling is unlikely. When synthetic rope was used, the chokersetters did not alter their operating practices to accommodate the difference in stiffness of the material. When pulling the line out, the chokersetters did not keep a steady tension on the skidding line causing backspooling. Once the cause of the problem was diagnosed, the chokersetters maintained a constant tension on the skidding line stopping most backspooling.

The Boman Mark IV carriage has a two speed internal drum that uses engine power to un-spool the line. When the loggers used synthetic rope with the slower speed, backspooling occurred less. However once the higher speed was applied, the loggers were unable to maintain a constant tension on the skidding line. This directly led to a higher occurrence of backspooling.

Site 4 – Koller K300 Mainline Trial

The results from site 4 indicated a difference between steel wire rope and synthetic rope for the inhaul element. Each element of the cycle was modeled as a separate linear regression and produced an equation to predict the elemental time. The regression relationships developed from the data are in Table 5.

Outhaul – The outhaul element is related directly to the outhaul distance the carriage must travel during a turn. The mean time per cycle was 38 cmin. The mean distance was 168 feet with a minimum of 15 feet and a maximum of 250 feet.

Table 6. Delay free regression equations[a] for elemental / occurrence[c] model for Koller K300 mainline trials

Element	Relationship	R^2	n
Outhaul	27.25 + 0.07*dist	0.26	101
Lat out	0.98*latout dist	0.76[b]	60
Hook	50.31 - 38.51*preset(0/1)	0.29	102
Lat in	28.05 + 0.84*latin dist	0.30	69
Inhaul	0.53*dist + 31.71*synthetic (0/1) - 0.41*dist*synthetic (0/1)	0.87[b]	103
Down	12.83		100
Unhook	7.08 + 7.08*no. logs	0.22	103
Up	6.72		100

[a]Units are in cmin (1/100 min), feet

[b]Model was forced through the zero intercept, R^2 values are artificially higher

[c]Of the 103 cycles collected, elements with less than 103 observations must be a pro-rated summation of the elemental regression equations to estimate the total cycle time

Lat out – The lateral out element was only measured from the first lateral out distance to the hook point. Because the mean time for steel was 33 cmin with a respective distance of 31 feet and synthetic was 27 cmin and 22 feet, the first lateral out / hook was the only portion of the lateral out element analyzed. The first lateral out / hook occurred 100% of the turns measured, 33% of the turns measured had a second lateral out / hook, while only 13% had a third lateral out / hook component. The mean time per cycle was 35 cmin. The mean distance was 31 feet with a minimum of 5 feet and a maximum of 90 feet.

Hook – The hook time did not differ significantly for the trials using steel wire rope or synthetic rope ($p = 0.746$). The mean time per cycle was 30 cmin. The minimum time per cycle was 4 cmin; the maximum time was 210 cmin.

Lat in – The mean time per cycle was 58 cmin. The mean distance was 36 feet with a minimum of 5 feet and a maximum of 125 feet.

Inhaul – The inhaul time differed significantly for the trials using steel wire rope and synthetic rope ($p = 0.003$ for synthetic indicator variable; $p < 0.0001$ for interaction term [synthetic indicator * inhaul distance]). The mean time for inhaul was 57 cmin. The mean inhaul distance was 167 feet. The minimum distance was 15 feet; the maximum 250 feet. This difference cannot be explained; however, different yarder operators are thought to be the cause of the difference.

Down – The down element did not differ significantly (p = 0.113) for the steel wire rope and synthetic turns. The mean time for the down element was 13 cmin. The minimum time was 5 cmin; the maximum 37 cmin.

Unhook – The unhook element was directly related to the number of logs per turn. The mean time to unhook was 24 cmin per turn. The average number of logs per turn was 2.36 with a minimum of 1 log and maximum of 5 logs per turn.

Up – The up element did not differ significantly (p = 0.149) between steel wire rope and synthetic rope. The mean time for the up element was 7 cmin. The minimum time was 3 cmin; the maximum 13 cmin.

Delays – The delay times were summarized by type (Table 7). The majority of the delays (61 percent) during the steel trials were related to landing activities. The majority of delays (71 percent) during the synthetic trials were related to the carriage and repositioning log activities.

Table 7. Percent of delays by type for Koller K300 mainline trials

Delay Type	Steel	Synthetic
Adjust Chokers	10%	1%
Carriage	6%	26%
Landing	61%	12%
Other	2%	4%
Reposition logs	12%	45%
Talking	3%	6%
Unknown	5%	3%
Walking	0%	0%
Yarder	1%	2%

SUMMARY

The trials involving the Koller K300 mainline showed a significant difference between steel wire rope and synthetic rope for the inhaul element. Since no independent variables were measured other than yarding distance, this difference cannot be explained. However, two yarder engineers ran the yarder during these trials. A difference in their operating practices may be the cause of the difference.

This trial used the Koller SK-1 carriage which is a manual slackpulling carriage. Many logging contractors use mechanical slackpulling carriages with an internal engine to pull slack. The basis for this trial was not to project the results to other types of carriages, but to assess the differences between steel wire rope and synthetic rope in a winching line application.

The results from this trial show the effects of a manual slackpulling carriage using synthetic rope. Because synthetic rope is lightweight, mechanical slack pulling carriages may not be needed if line can be pulled without much effort.

The result of running synthetic rope over sheaves and through a carriage will help researchers understand how mechanical slackpulling carriages might be modified for synthetic rope.

The other benefit of a mechanical carriage is the ability to clamp on the skyline or the mainline with a mechanical brake. The carriages during our trials were not clamping carriages. It is unclear how the clamping feature on these carriages will affect synthetic rope.

However, if synthetic rope can be used in a mechanical slackpulling carriage and the slackpulling feature not needed, then engine size may be reduced and only needed to provide a power source for the skyline clamp. The reduction in the number of components in the carriage will also result in a lower cost to manufacture the carriage and thus a lower cost to the logging contractor.

Our observations during this trial also indicate increased line spooling is possible. With steel wire rope, the capacity of the drum was around 1100 feet, but with synthetic rope, we spooled over 1200 feet onto the drum. We believe that 1300 feet of synthetic mainline is possible on this type of drum. Increasing the spooling capacity has a direct effect on maximum yarding distance for the operation because more skidding line is available.

ECONOMIC CONSIDERATIONS

Economics are important for every logging contractor. In most of our trials, initial cost for synthetic materials was a significant drawback.

The use of synthetic rope has many benefits that are difficult to value in monetary terms. Logging contractors are hesitant to try synthetic rope unless the benefits are assessed in dollar values. Synthetic rope costs on average 2-4 times that of similar diameter steel wire rope. This additional cost is difficult to overcome unless logging contractors can see the added benefits of using synthetic rope.

Gains in efficiency could offset some of all of the costs of synthetic rope at the current price structure. In our trials, we recorded stand volumes, log volumes, and or logs per turn. This information could be used at a later stage to help develop a benefit-cost ratio for synthetic rope users.

Caterpillar D6 Trials

For the Caterpillar D6 trials, we observed increased winching distances. If winching distance increased even twice that of steel wire rope, a decrease in maneuvering time would result. This would directly effect logging productivity, reduce fuel consumption for logging machinery, and provide soil benefits. Some logging contracts call for specified skid trail spacing. Designed experiments would likely show production differences for this type of operation.

John Deere 650G Trials

During our trials with the John Deere 650G, a difference existed for the lateral out element (Figure 13). At 20 feet lateral out distance, a 15% difference exists between steel wire rope and synthetic rope. When lateral out distance extends to 50 feet, a 70% difference exists. A mean distance of 22 feet equates to a 21 percent decrease in task time for synthetic rope. This time difference can result in a 0.6 minute increase at 20 turns per day (22 feet), to a 3.4 minute increase per day (50 feet). Such small time differences for part of the turn would likely be overshadowed by the operator's ability to gain more turns per day because of less fatigue when using synthetic rope.

The loggers commented that they felt "better" at the end of the day and were not as tired as they had been when using steel wire rope.

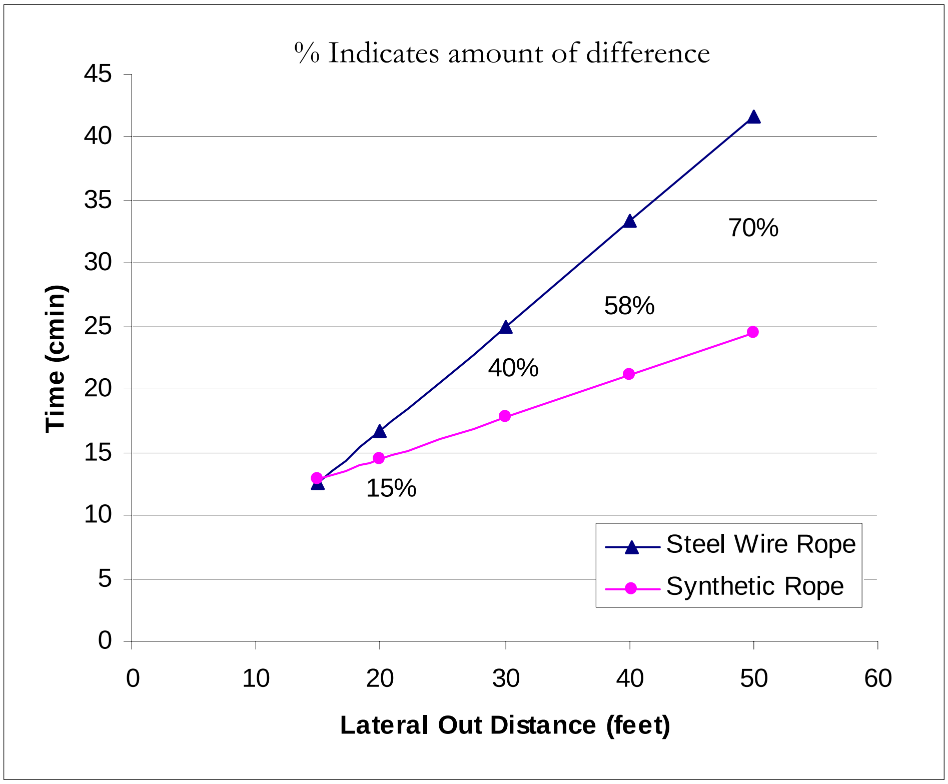

Figure 13. Increase in efficiency for lateral out element – John Deere 650G winching trial

Boman Mark IV Trials

The trials involving the Boman Mark IV carriage did not show any significant differences between steel wire rope and synthetic rope. However, as additional research is conducted to specifically look at the lateral out element, differences would likely exist between the two rope materials. Circumstances where long, side-hill pulls or uphill pulls are required might be situations where such differences will exist.

Koller K300 Trials

The trials involving the Koller K300 mainline showed a difference in the inhaul element. Since no independent variables were recorded other than distance, this difference cannot be explained.

Although the trials with the Koller K300 mainline showed no significant differences other than the inhaul element, trials involving synthetic rope in this application under different operating circumstances may show a difference in the lateral out element. These circumstances may include long, side hill pulls, or uphill pulls where synthetic rope has an obvious advantage over steel wire rope. Future research should focus on these designs to generate potential outcomes.

CONCLUSIONS

There were large variations in the cycle times for many of the applications studied. This preliminary investigation suggests synthetic rope is suitable for some winching applications especially when considering ergonomic benefits. Further trials are necessary under more controlled research conditions to assess differences between steel wire rope and synthetic rope for winching applications.

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CHAPTER 4

SURVEY RESULTS

A survey of a very small set of eight logging contractors was conducted to assess their opinions and experiences with synthetic rope. The designed questionnaire collected responses through a phone survey. General information about their uses of synthetic rope, as well as specific questions on rope costs, ergonomic benefits, and rope properties was collected. Questionnaire materials are found in Appendices three and four. Loggers also offered anecdotal experiences about using synthetic rope. All of the surveyed logging contractors initially heard about synthetic rope through Oregon State University presentations, logging conferences, or trade magazine articles.

The average experience level of surveyed loggers was 24 years. Five of the eight logging contractors classified themselves as owner / operators. Use of synthetic rope ranged from 2 months to 7 years, averaging 24 months for logging applications. The most commonly used applications were guylines, intermediate support lines, and tree straps. However, four logging contractors used synthetic rope winch lines.

When asked the weight of synthetic rope compared with steel wire rope, all logging contractors reported a weight of $1/10^{th}$ the weight of steel wire rope. They were given the choices of ½, ¼, $1/10^{th}$, or $1/20^{th}$ the weight of wire rope.

All loggers surveyed reported they had experienced a jagger from steel wire rope. Some offered that synthetic rope was more suitable for logging because synthetic rope does not have jaggers.

All eight loggers reported that the coiling and storage of synthetic rope was the same or better than coiling and storage of steel wire rope. Five of the eight loggers reported that synthetic rope was much better than steel wire rope to coil and store (Figure 14).

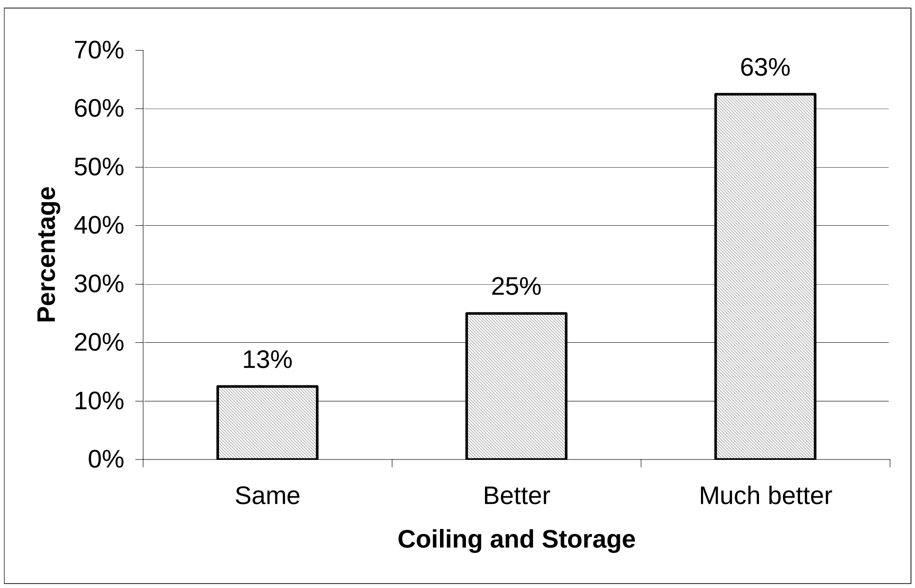

Figure 14. Responses on coiling and storage of synthetic rope compared with steel wire rope

Thirteen percent of loggers said that synthetic rope was more difficult to use than steel wire rope. The remaining eighty-seven percent said its ease of use was the same or better than steel wire rope (Figure 15).

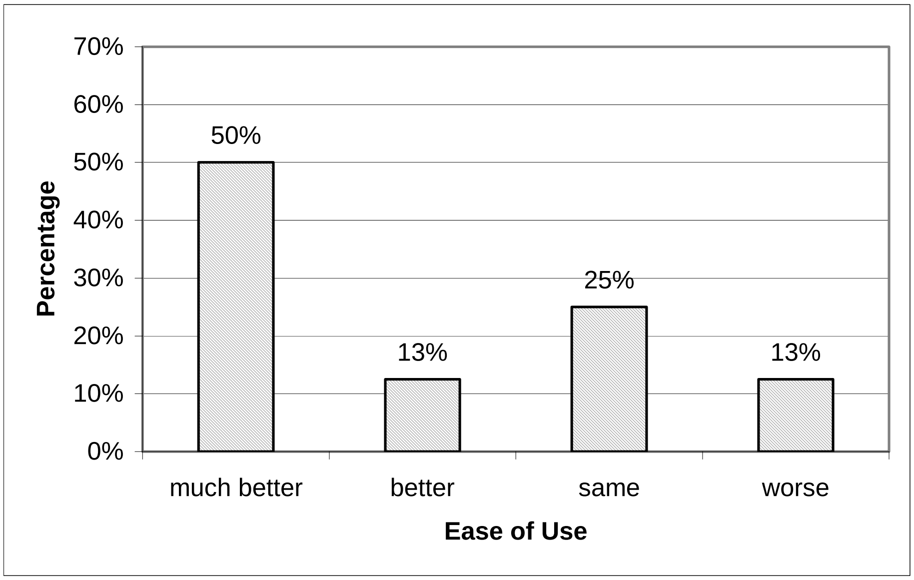

Figure 15. Ease of use of synthetic rope compared to steel wire rope

Seventy-five percent of loggers reported exposure of synthetic rope to hydraulic oil, saw gas, and diesel fuel. Forty-four percent of loggers reported abrasion as the most significant source of damage to synthetic rope during use.

When asked what end connectors they employed, fifty-eight percent of loggers used spliced eyes and shackles. Another sixteen percent of respondents reported temporarily using knots with synthetic rope. Sixteen percent of surveyed loggers also reported using some type of nubbin or ferrule.

Twenty-five percent of loggers reported that the synthetic rope did not meet their expectations. Seventy-five percent reported that it met or exceeded their expectations (Figure 16).

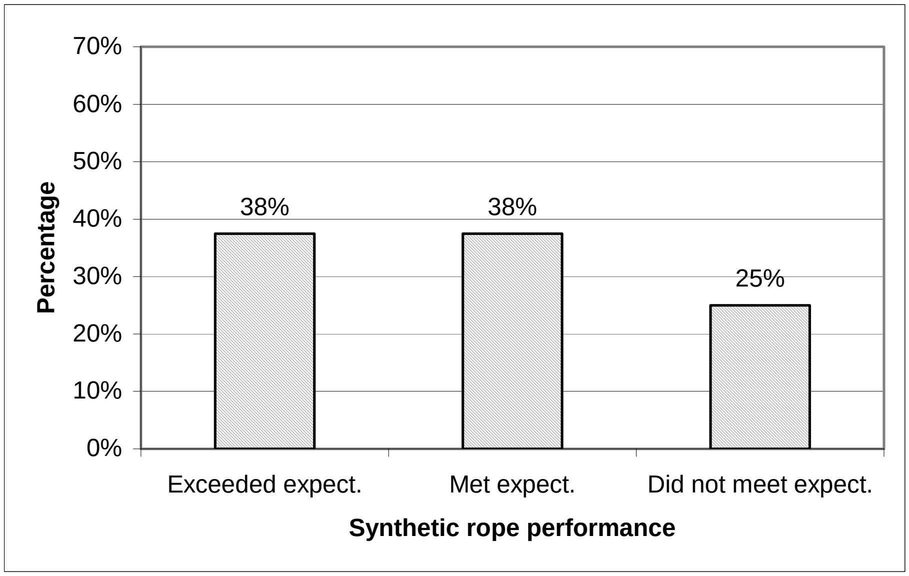

Figure 16. Synthetic rope performance

All loggers reported that the cost of materials was important (thirty-seven percent) or very important (sixty-three percent), (Figure 17). All loggers also reported the ergonomic benefits of synthetic rope as very important.

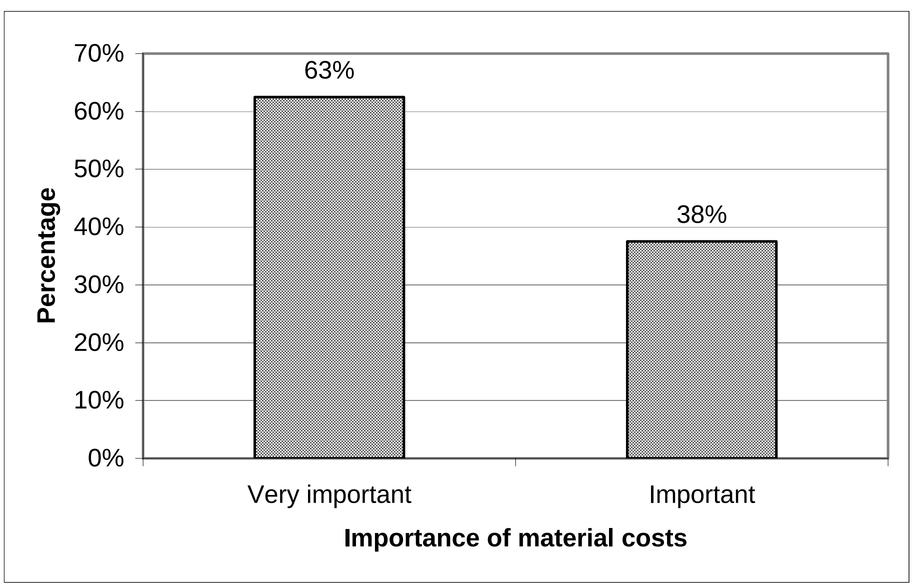

Figure 17. Importance of material costs

Sixty-three percent of loggers reported a willingness to pay twice the current price of steel wire rope for synthetic rope. One logger reported he would spend five times that of steel wire rope for synthetic rope (Figure 18).

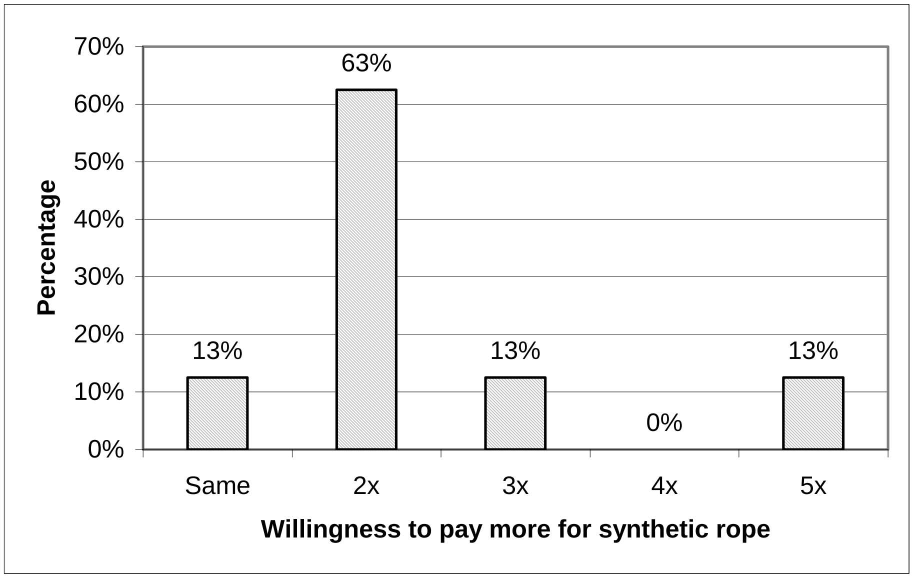

Figure 18. Willingness to pay more for synthetic rope than steel wire rope

Eighty-eight percent of loggers surveyed reported that the ergonomic benefits of synthetic rope outweighed the additional cost of the material; only one logger reported the ergonomic benefits of synthetic rope did not outweigh the additional cost of the material.

Overall, synthetic rope was generally accepted by most logging contractors surveyed. Cost was the most significant factor for using synthetic rope. Most loggers reported a willingness to pay twice the cost of steel wire rope. Synthetic rope is more likely to be adopted by owner / operators who are aware of both the economic tradeoffs and ergonomic benefits of its use.

CHAPTER 5

RECOMMENDATIONS AND FUTURE RESEARCH WITH WINCHING TRIALS

Our research trials revealed many issues and questions for synthetic rope use in logging. The trials were not designed experiments but rather industry trials of synthetic rope to help learn about its applications, problems, and opportunities. We also identified useful approaches for future designed research efforts.

Site 1 – Caterpillar D6 Crawler Tractor Winching Trial

During this trial the operator increased winching distance due to the light weight and ease of the rope's use. However, as winching distance increased, the horizontal winchline angles in the timber stand increased as well. The short winching distances (<50 feet) used in the past with steel line apparently did little damage to the residual trees. As winching distances increase (>100 feet) more careful winching and log selection may be needed to reduce stand damage from winchline rubbing. Also, it is unclear whether synthetic line causes more or less damage to trees than steel line, and wear and damage to the synthetic line itself from tree rubbing should be examined.

During our trials with steel wire rope we observed that the logging contractor usually maneuvered as close to logs as possible before hooking a turn. This maneuvering likely caused additional soil impacts not occurring when synthetic rope was used. Because synthetic rope is lightweight and easy to pull a few extra feet, the operator did not maneuver as much when selecting turns and we saw less soil disturbance during the operation. A series of experiments aimed at assessing soil impacts, skidding efficiencies and operator workload were suggested from this Eastern Oregon trial.

Site 2 – John Deere 650G Series IV Crawler Tractor Winching Trial

Although our brief data collection and analysis showed differences between synthetic rope and steel wire rope, we need better research designs. Our observations during this trial revealed the need for effective operator education and control. We observed damaging operating practices at times that led to ultimate failure of the synthetic rope. By design, we originally did not provide full training to the operator on operating practices and intervened after rope failures. The reluctance of operators to change their practices is noteworthy. While these poor operating practices led to premature failure of the synthetic winchline; the operator acknowledged such practices might have led to failure in steel wire rope more frequently as well. Sufficient operator training and experience with synthetic rope as a winchline should precede research trials so differences can be attributed to the rope type rather than operator miss-use.

Site 3 – Boman Mark IV Internal Drum Carriage Trial

Because of differences in research conditions, the trials with the Boman carriage showed no significant difference between steel wire rope and synthetic rope. Future research should be a designed study to assess the operational characteristics of the two materials where long side-hill or uphill pulls are required from the carriage under comparable skyline positions. For example, using half of a corridor yarded with steel wire rope and half with synthetic rope. We also had difficulties modifying loggers' operating practices to accommodate the use of synthetic rope, and once again, observed that logger education is needed at the operational level before progress can be made at the research level.

Site 4 – Koller K300 Mainline Trial

The synthetic rope mainline of the Koller K300 yarder proved satisfactory for the period of the trials and afterwards but production efficiencies were difficult to measure for such light lines as those used. In these trials, we observed how important the carriage / mainline interactions were to yarding efficiencies. Synthetic rope can be used in a manual slackpulling carriage of a design like that of the Koller SK-1 carriage.

Many contractors currently use mechanical slackpulling carriages of various designs. Modifications for using synthetic rope would be needed for carriages that pull the mainline through the carriage (as in the Koller carriage) or for carriages with an internal skidding drum (Boman carriage). The use of tensioning devices for synthetic rope may be needed for some carriage designs to avoid “diving” of the line onto the skidding drum.

CHAPTER 6

GENERAL CONCLUSIONS FOR THE PROJECT

This preliminary investigation of synthetic rope as an alternative for steel wire rope in the logging industry shows synthetic rope is a suitable candidate for some applications.

Synthetic rope is more likely to be adopted by owner / operators who are aware of the economic tradeoffs and ergonomic benefits of synthetic rope. Additionally, based on evidence from our project, we would agree with a statement made by Jean Dunnigan (1993) that says, "Although vulnerable to sharp metal edges, synthetic rope can serve the user well who uses good judgment and takes care of their equipment!"

Synthetic rope used in static rigging applications showed that guylines, intermediate support lines, tree straps, and snap guylines were suitable candidates for use with synthetic rope. Although we did not measure ergonomic benefits in these trials, most logging contractors reported easier use and less physical exertion with the use of synthetic rope for static rigging applications. However, initial cost of the rope material was a significant drawback for most logging contractors. Additional research is needed to determine damage and wear criteria for synthetic ropes in these applications.

Synthetic rope used for winching applications showed mixed results. Trials involving winching applications on skidders and crawlers showed positive benefits from the use of synthetic rope such as easier lateral pulling, increased fairlead angles, and reduced worker effort. The trials involving the John Deere 650G showed a difference in the lateral out element.

Our trials involving the Boman Mark IV internal drum carriage produced no significant differences between steel wire rope and synthetic rope for delay-free cycle times. However, many observations were made that will assist future research for these types of applications. This trial provided valuable information in the spooling characteristics of synthetic rope under high tension and high speed line pulling. Future studies with carriage applications should focus on designed trials where differences between materials can be assessed.

The Koller K300 mainline trials proved synthetic rope is suitable as a running line. Because no difference was detected in our study period, additional research should focus on designed experiments where long side-hill or uphill pulls are required. In these situations, synthetic rope has an advantage in weight over steel wire rope.

Although very early in development, synthetic rope has merit in the logging sector. The future of synthetic rope lies in the hands of the users. As more research and additional applications are discovered, loggers can apply this research to practical operations. It was apparent in our research that initial cost of the rope material is a significant drawback for most logging contractors. If costs for the material remain high, the future of synthetic rope may be limited in logging applications.

It is difficult to show the "accident that did not happen", and although synthetic rope has properties that lend to reduced workloads, cost will be a major deterrent for loggers if they cannot realize the additional benefits.

Educating loggers about the safety, workload, and ergonomic benefits of synthetic rope may help them to put the increased cost of synthetic rope into perspective.

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APPENDICES

Appendix 1 – Logging Cooperators with the Project

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G & B Logging
Monmouth, OR 97361

Richard Van Damme
ACME Manufacturing, Inc.
Springfield, OR 97478

Jim Gahlsdorf
Gahlsdorf Logging
Salem, OR 97304

Dan Komning
Dakom Logging
Mt. Vernon, OR 97865

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Oregon State University College of Forestry
Corvallis, OR 97331

Steve Pilkerton
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Doug Schlatter
Doug Schlatter Contracting, Inc.
Roseburg, OR 97470

Hank Scott
Scoggins Creek Harvesting Corporation
Gaston, OR 97119

Ben Stringham
Stringham Logging
Corvallis, OR 97330

Appendix 2 – Time Elements for Synthetic Rope Trials

Site 2 – John Deere 650G Series IV Crawler Tractor Winching Trial

This trial contained the following elements:

Outhaul – the time to travel out to the logs

Lat out – time to pull winchline out to first log

Hook 1 – time to hook first log

Mount – time to walk to crawler and get on machine

Winch in – time to winch turn in to crawler fairlead

Winch/Crawl ahead – time to position logs and crawler before inhaul

Inhaul – time to crawl to landing with turn

Unhook – time to unhook turn

Decking – time to deck logs on the landing

Site 3 – Boman Mark IV Internal Drum Carriage Trial

This trial contained the following elements:

Outhaul – time for carriage to travel out and stop

Lateral out – time to pull line a specified distance

Hook – time to hook a turn

Lateral in – time to winch turn to carriage

Car ahead – time to position carriage

Inhaul – time to pull carriage to landing and stop

Down – time for turn to reach the ground

Unhook – time to unhook turn

Up – time to winch load hook up

Site 4 – Koller K300 Mainline Trial

This trial consisted of the following elements:

Outhaul – time for carriage to travel out

Lateral out – time to pull line a specified distance to the first log

Hook – time to hook first log

Lateral in – time to winch turn to carriage

Inhaul – time to pull carriage to landing

Down – time for turn to reach the ground once carriage is clamped

Unhook – time to unhook turn

Up – time to winch load hook up

Appendix 3 – Questionnaire and Survey Transcript

Submitted by:

Jared Leonard and John Garland

Department of Forest Engineering

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Corvallis, Oregon 97331

Purpose:

We are performing this survey to acquire knowledge for our research on the use of synthetic rope as a means of replacement for steel wire rope in logging applications. This survey will be used to collect subjective data, collect data on the use of synthetic rope by logging contractors, and used in publications of our research.

Transcript:

Hi **[logging contractor]** my name is Jared Leonard. I am with the synthetic rope research team at Oregon State University in the Forest Engineering Department. The synthetic rope research team is composed of John Garland, Steve Pilkerton, Joel Hartter, and myself. We are conducting a survey to collect information on synthetic rope for use in logging. I estimate this survey will take 20 minutes to complete; do you have time for me to ask you a few questions? If yes **[1]** If no, when is a good time for you and I to complete this survey?

[1] The purpose of this survey is to collect information about the uses of synthetic rope for logging applications. All information collected is strictly confidential and will be aggregated so no names will be associated with specific answers to the survey. This information will not be given to employers, fellow workers, or any other persons. Do you have any questions before we begin?

Read **[Question 1]**

Read **[Question 2]**

Read **[Question 3]**

Read **[Question 4]**

Read **[Question 5]**

Read **[Question 6]**

Read **[Question 7]**

Read **[Question 8]**

Read **[Question 9]**

Read **[Question 10]**

Read **[Question 11]**

Read **[Question 12]**

That completes our survey. Thank you very much for taking the time to talk with me. Would you like a copy of our results from this survey? If yes, **[obtain address]**. If no, thanks again.

Appendix 4 – Synthetic Rope Questionnaire

Name: ______________________________

Logging Experience: ____________________ years

Employer: ___________________________

Current Job Title: _______________________

Phone Number (s): _____________________ #1

_____________________ #2

1. Have we completed an ergonomic set of questions with you?

2. How did you hear about synthetic rope?

3. How long have you used synthetic rope?

4. What applications have you used synthetic rope for?

Applications	Frequency (daily, weekly, monthly, etc)	How Long (months, years, etc)

5. Rope features:

A. Weight: compared with steel wire rope, how much do you think synthetic rope weighs?

__ 1/2 as much

__ 1/4 as much

__ 1/10 as much

__1/20 as much

B. Jaggers: Have you ever had a jagger with steel wire rope?

__ Yes

__ No

C. Coiling / Storage: compared with steel wire rope, does synthetic rope coil and store-

__ Much better

__ Better

__ Same

__ Worse

__ Much worse

D. Chemical exposure: what chemicals have you exposed synthetic rope to?

E. Damage: what damage have you caused to synthetic rope?

F. Ease of Use: compared with steel wire rope, does synthetic rope perform-

__ Much better

__ Better

__ Same

__ Worse

__ Much worse

G. End Connectors: what end connectors have you used to secure synthetic rope?

6. Has synthetic rope performed as well as you thought it would?

__ Exceeded expectations

__ Met expectations

__ Did not meet expectations

7. When compared with steel wire rope, how has synthetic rope performed?

    __ Exceeded expectations

    __ Met expectations

    __ Did not meet expectations

8. Concerning the cost of materials, how important is cost?

    __ Very important

    __ Important

    __ Not important

9. How important are the ergonomic benefits of synthetic rope?

    __ Very important

    __ Important

    __ Not important

10. How much more would you be willing to pay for synthetic rope than steel wire rope?

__ Same as steel

__ 2x

__ 3x

__ 4x

__ 5x

11. Do the ergonomic benefits of synthetic rope outweigh the cost of the material?

__ Yes

__ Somewhat

__ No

12. Are there any other comments you would like to make regarding the use of synthetic rope?