SYNTHETIC ROPE USE IN LOGGING WINCHING APPLICATIONS

Stephen J. Pilkerton, John J. Garland, Jared M. Leonard, and John Sessions

Research Forest Engineer, Professor, Graduate Research Assistant, and Professor; respectively;
steve.pilkerton@orst.edu
Oregon State University, Forest Engineering Department
215 Peavy Hall, Corvallis, OR 97331 USA

ABSTRACT - The use of ultra high molecular weight polyethylene (UHMWPE) fiber rope as a replacement for steel wire rope shows beneficial properties with the use of synthetic ropes in static line applications such as guylines. The promise shown establishes the basis for expanding its use to running lines for improvements in logging safety, worker ergonomics, and economic efficiency. Research is investigating the applicability of synthetic ropes to dynamic applications including winch lines on crawler tractors and rubber-tired skidders, a carriage dropline, and a mainline winch on a Koller K-300 cable yarder. Required rigging connection modifications are discussed. Observed durability and wear of the synthetic rope are reported. Subjective evaluations by machine operators and researcher observations are briefly summarized. Future research ideas are outlined.
KEYWORDS: fiber ropes, cable harvesting, line logging

INTRODUCTION

The potential of rope constructed of ultra high molecular weight polyethylene fibers (UHMPWE AmSteel Blue 12 strand braided rope[1]) to replace wire rope in logging applications has been shown at previous COFE meetings (Garland et al., 2001) and elsewhere (Pilkerton et al., 2001). The rope's strength is similar to steel wire rope of the same nominal diameter but it weighs only about 1/9th as much. Current research is continuing into the specific static line applications in cable logging (Leonard et al., 2003). Designed experimental trials on various potential end-connectors are underway to assess connections of synthetic rope to machines, winches, and wire rope. This paper describes experiences with winching applications on ground-based equipment and in cable logging.

Three research and development projects funded by Oregon's Occupational Safety and Health Administration Worksite Redesign Grants show potential ergonomic improvements for workers using synthetic rope in place of steel wire rope (Garland et al., 2002). In addition, the research was designed to place synthetic rope in the hands of logging contractors to evaluate its potential applications, specific problems and opportunities for improvements. The nature of the research and development efforts with contractors diminishes the opportunity of designed studies in favor of identifying problems across novel uses and subjective assessments by users. Only one type of synthetic rope was selected for our studies of dynamic uses on winches with potentially different type rope applications likely to be suggested from our pilot trials. Economic potentials are always of high interest when synthetic ropes may cost from 2-4 times comparable wire ropes, and our studies begin such documentation but await further designed studies on economic benefits.

The comparison of synthetic rope to steel wire rope is hampered by the lack of research on wire rope in logging applications, especially related to wear and damage. Serviceability of wire rope

---

[1] AmSteel Blue is a product of Samson Rope Technologies, Ferndale, WA (samsonrope.com). Mention of trade names is not an endorsement by Oregon State University.

in logging is often estimated from manufacturer's guidance (Williamsport Wirerope Works, Inc. 2000) or guidance provided by safety codes (Oregon Admin. Rules, Forest Activities Code, Division 7: www.orosha.org/standards/div_7.htm). It turns out wire rope is not homogenous and strength and service vary by design, manufacturer (domestic versus imported), and specific applications. Torgersen (2002) recently experimentally evaluated selected wire ropes for their endurance over cyclic loadings and their service life related to varying sheave diameters and found significant differences. Earlier work with synthetic ropes as yarder guylines (Takumi 1998) and as ground-based winch lines (Lapointe 2000; Golsse 1996; Dunnigan 1993) were not so positive as to stimulate further trials; however, the rope types and applications were different from those we report on in this study.

Our trials include: a large, crawler tractor operation in eastern Oregon; two western Oregon operations using a mid-size crawler and skidder; a Boman carriage operation using synthetic rope as the dropline; and use of synthetic rope as the mainline on a Koller K-300 yarding operation (mention of trade names is not an endorsement). All trials used AmSteel Blue synthetic rope in sizes from 3/8 to 7/8-inch diameters to replace wire ropes of comparable diameters and strengths. Our observations and subjective assessments describe these applications and suggest potential economic benefits and future research needs from the trials.

CASE STUDY DESCRIPTIONS

Eastern Oregon Crawler Tractor Trial: A logging contractor performed sanitation thinnings in mixed ponderosa pine (*Pinus ponderosa*) and western juniper (*Juniperus occidentalis*) stands affected with Black Pineleaf Scale (www.fs.fed.us/r6/nr/fid/fidls/fid191.htm) to remove dead, dying, and severely compromised ponderosa pines. The terrain was broken, and slopes exceeded 30 percent in some areas. The prime mover was a Caterpillar D6C-10K crawler tractor (140 horsepower, 30,600 pounds) outfitted with a Carco F50 integral arch winch. The contractor typically spooled 75 feet of 7/8-inch swaged steel wire rope. For this trial, 120 feet of 7/8-inch AmSteel Blue rope was installed. The operator typically drove to logs, pulled winch line and set pear-ring and toggle chokers to the logs (Figure 1). Turns were usually of 3-4 logs.

Figure 1. Operator pulling synthetic winch line and chokers to ponderosa pine logs.

Western Oregon Crawler Tractor Trial: Contract operations consisted of clearcut harvest of a 40-year old Douglas-fir (*Pseudotsuga menziesii*) stand. The terrain was uniform, with slopes to 30 percent. The crawler was a John Deere 650G crawler tractor (90 hp, 19,000 pounds) with a JD 4000 series integral arch winch. One hundred twenty feet of 5/8-inch AmSteel Blue rope was installed with a pear-ring and toggle choker system. The operator drove to the logs and collected 3-4 logs per turn.

Western Oregon Skidder Trial: The OSU Forest Engineering department Student Logging Program utilized a John Deere 540 B rubber-tired skidder (90 hp, 16,800 pound) to thin 40-50 year old Douglas-fir stands on slopes less than 20 percent. One hundred twenty-five feet of 3/4 –inch AmSteel Blue rope was used with a round-ring and toggle choker system. The skidder operator set his own chokers or had preset turns of 3-4 logs hooked by a choker setter.

Skyline Carriage Dropline Trial: A logging contractor operated a standing skyline system with a Madill 071 yarder and Boman Mark IV carriage (3800 pounds) in a modified seed tree (six trees per acre for wildlife) harvest unit of 100-year old Douglas-fir. Cable corridors ranged from 15 to 60 percent. The carriage used a powered (106 hp) winch for pulling logs into the carriage. The 2-speed winch also powered out (rotationally "pushed") the steel wire rope from the carriage for lateral slackpulling. While the contractor utilized a 5/8-inch swaged steel wire rope dropline, a 5/8-inch AmSteel Blue rope was installed for this trial. Chokersetters set 2-4 logs per turn and controlled carriage winching operations by radio signals.

Cable Yarder Mainline Trial: The OSU Forest Engineering department Student Logging Program utilizes a Koller K300 two drum yarder and SKA-1 carriage for standing skyline yarding operations (Figure 2). Thinnings on steep slopes (greater than 45 percent) of 40-50 year old Douglas-fir stands are typical; however, our trial included a 1-acre patch clearcut of larger stems. The original 3/8-inch steel mainline was replaced with a 3/8-inch AmSteel Blue rope. A round ring and toggle system is utilized to preset 2-4 logs per turn.

Figure 2. Koller K300 yarder, SKA-1 carriage, and yarded turn at landing.

FINDINGS

The owner-operator skidding in the ponderosa pine was pleased with the ease of line pulling, especially on difficult uphill pulls. Operational times were decreased, sometimes remarkably. The operator stated that on one difficult uphill pull, a turn would have taken him 30 minutes with steel, but he did it in about 10 minutes with the synthetic line. The operator also had occasional pulls over rimrock outcroppings and around residual juniper stems -- both are abrasive materials. The synthetic skidding line failed (broke) late in the trial period. We did not see this failure and do not know the failure mechanisms. The operator said the turn was normal size. The operator was able to eye splice the line onto the toggle and continue operating. This line has now been removed for residual strength testing. The operator requested a 50 percent longer synthetic line to continue the trial. He now uses a synthetic winch line twice as long as the previous steel line.

The employee operating the JD 650 crawler tractor had similar positive experiences. The pear-ring chokers however occasionally twisted 180 degrees and make a bight on the skidding line winch hindered slackpulling. The operator also encountered two failures due to rope breakage. These failures were not observed by us and we do not know the failure mechanisms. We think the sharp casting edges of the pear-rings may create cutting edges. Subsequent rings have been smoothed with a grinder prior to use. The next trial will substitute round-ring chokers (with smoothed casting edges) and changed operating procedures.

The student skidding trials have been more successful in terms of duration. No operational failures have been encountered. Tufting of the rope due to broken exterior filaments of the strands is the only visible degradation of the rope during use. However, the synthetic rope will not sustain abuse as steel wire rope. A student worker wrapped the synthetic skidding line over sharp grab hooks to attempt to pull an artificial earth anchor. The rope was severed. This rope had 2.5 years of use prior to this event and is now scheduled for residual testing.

The carriage dropline trial provided information on the failure modes. Sharp edges on the used carriage cut the trial rope on a low deflection corridor with perpendicular lateral pulls. The adage "you can't push a rope" was confirmed in application of this winch design for spooling off the skidding line. The two-speed winch created back-spooling hang-ups on the drum. When the rigging crew applied minimal, constant pulling tension during lateral slackpulling, the backspooling was eliminated. The rope failed once on the drum as the yarder engineer spooled and unspooled the drum to release the dropline. In spite of the problems, the owner would like to again try the rope in the near future.

The mainline trial has been successful to date. One rope failure has been encountered near the load hook. A "strand interchange" (knotting of old and new spool for a strand) during manufacturing was located near the break and suspected to be the failure mechanism. While our early lateral pulls are not substantially different (due to minor differences in unit line weight with 3/8-inch steel rope), there is a noted difference in the reduced sag which develops with the synthetic mainline. This reduces the pulling effort required. Spooling capacity increased on the drum due to better layering of the synthetic line. The K300 mainline drum capacity is rated at 1150 feet of steel line. We installed approximately 1300 feet of synthetic rope and still have additional drum capacity.

DISCUSSION

Our efforts to put the synthetic rope in the hands of the users have provided significant information on failure and wear mechanisms. Treating synthetic rope as steel rope has provided future operational changes and/or rope configuration and materials changes for improvement. None of the failures were so different than similar steel wire rope failures as to give concern about using synthetic rope. In fact, some synthetic rope failures were similar to "expendable" failures in steel wire rope winch lines.

Wear and Replacement Issues: Wire rope and synthetic rope are most often evaluated for replacement by visual indicators or simple measures on the rope itself (element counts, diameter measurement, etc.). While wire rope standards may exist for allowable wire breaks for some industries (elevators, material lifts over personnel, etc.), they do not apply to logging where work practices call for personnel to be in the clear when loads are on the lines. Some rope elements in logging are considered "expendables" because of the wear they receive such as chokers or the end sections of winch lines and drop lines. Similarly, existing retirement guidelines for arborists' use of synthetic ropes are not applicable to logging applications. Visual evidence from abrasion, corrosion, crushing, diameter reductions, stranding, bending and shock loading for wire and synthetic ropes differ as follows.

Abrasion -- Abrasion in wire rope causes broken wires and replacement is based on a specified number of broken wires. Synthetic rope initially fuzzes up from broken filaments that produce a protective cushion but when braided rope is worn 25% from abrasion it should be replaced. Powder inside the rope indicates internal abrasion (The American Group 1997).

Corrosion – With wire rope, pitted wire surfaces and breaks indicate corrosion and corrosion is difficult to assess for interior damage. AmSteel Blue synthetic rope is not affected by corrosion for the chemicals typically encountered on logging operations.

Crushing – With wire rope, flattening of strands from poor spooling and other causes damages it and reduces its strength. Synthetic rope may flatten and glaze due to tension around pins and sheaves but will return to a round shape when worked by hand.

Diameter reductions -- Wire rope diameter reduction is a critical retirement factor due to excessive abrasion, loss of core support, inner wire failure and so forth. Synthetic ropes may actually increase in apparent diameter from abraided filaments and material inside the rope itself. Localized diameter reductions, flat areas, and lumps and bumps in the synthetic rope are of concern for replacement as well as ropes built up with dirt and debris.

Stranding -- Wire rope stranding occurs from various causes including kinking, twisting, or tight grooves leading to broken wires and "jaggers" (exposed broken wires) to such a degree the rope is unusable. Synthetic rope will have broken filaments and strands but no jaggers.

Bending – Wire rope manufacturers' recommended ratios of bending to rope diameters have seldom been met for wire rope in logging. Synthetic rope ratio recommendations are also larger than those found in logging practice.

Shock Loading – In wire rope, birdcaging (core protusion) is evidence of shock loading and seriously degrades rope strength. Synthetic rope is less subject to shock loading but fibers may have memory and may retain effects of shock loading during normal loads. We are continuing to assess wear criteria for synthetic ropes.

Economic Issues

Early research and development have identified economic potentials (Garland et al., 2001) but detailed results will need to come from designed studies and perhaps over long term trials. For example, a study with the dropline carriage where the crew pulls the skidding line along the ground may show differences. Ground skidding in difficult (steep, slippery, etc) terrain and/or on long pulls may show synthetic rope advantages. Plus, some of the economic benefits from synthetic rope accrue from a reduction in crew fatigue allowing additional production at the end of the day or important safety benefits from reductions in slips and falls. It is always a problem with safety improvements to show the accident that <u>did not happen</u> was the result of reduced fatigue.

Designed studies should be conducted to relate the circumstances under which synthetic rope shows advantages, is neutral, or is a disadvantage depending on the operating conditions. We now have information from our contractor trials to organize such studies.

FUTURE RESEARCH

The obvious question for running line research would be trials using synthetic rope as a skyline where the weight advantage could be significant in low deflection circumstances. The question of how a carriage might affect the skyline is still open for trial; however, the use of synthetic rope as a skyline extension not involving carriage passage is not a problem. The other obvious research trial would be as a rigging line (strawline) for a larger cable system. To date, we have not tried either of these possibilities.

Carriage designs that allow use of synthetic rope are needed besides those carriages that use a dropline winch arrangement. Clamping the carriage on the skyline presents a problem for carriage designers to avoid rope damage. Another intriguing prospect would be the use of synthetic rope with a self-propelled carriage which eliminates requirements for a yarder. Current models have small radius sheaves and damage the wire rope more than what synthetic rope might experience.

We look forward to future research trials.

REFERENCES

Dunnigan, J. 1993. Braided Kevlar^{tm} cable: Trials in skidding wood with an ATV. Forest Engineering Research Institute of Canada Field Note. No. 22. Pointe-Claire, Quebec. 2p.

Garland, J.J., Sessions, J., Pilkerton, S. and B. Stringham. 2001. Synthetic rope used in logging: Some potentials. Council on Forest Engineering Annual Meeting, held July 16-19, 2001, Snowshoe, West Virginia. Council on Forest Engineering. Corvallis, OR. 5p.

Garland, J.J., Sessions, J., Pilkerton, S. and B. Stringham. 2002. Using synthetic rope to reduce workloads in logging. Final report Worksite Redesign Program Oregon Occupational Safety and Health Administration. Forest Engineering Department, Oregon State University. Corvallis, Oregon. 28p. plus appendices.

Golsse, J-M. 1996. Initial tests of synthetic fiber mainlines for cable skidders. Forest Engineering Research Institute of Canada Field Note No 33. Pointe-Claire, Quebec, 2p.

Lapointe, M. 2000. Development of methods to minimize the breakage frequency of synthetic-fibre rope mainlines used on cable skidders. Bachelor of Science thesis, Forestry and Environmental Management, University of New Brunswick, Fredericton, Canada. 32p.

Leonard, J., Garland, J. and S. Pilkerton. 2003. Evaluation of synthetic rope for static rigging applications in cable logging. Council on Forest Engineering Annual Meeting, held September 7-10. Bar Harbor, Maine. Council on Forest Engineering. Corvallis, OR. 7p.

Pilkerton, S., Garland, J., Sessions, J. and B. Stringham. 2001. Prospects for using synthetic rope in logging: First look and future research, in Proceedings of the International Mountain Logging and 11th Pacific Northwest Skyline Symposium. 2001-A Forest Engineering Odssey. Eds. P. Schiess and F. Krogstad, College of Forest Resources. U. Washington. Seattle, WA. Dec. 10-12, 2001. CD ROM Media. 289p.

Takumi, U. 1998. Application of super fiber rope as a guyline for a mobile tower yarder. Proceedings of the IUFRO/FAO Seminar on forest operations in Himalayan forests with special consideration of ergonomic and socio-economic problems. Heinimann, H.R. and J. Sessions (eds.). Kassal University Press, GmbH. ISBN 3-933146-12-7. 160p.

The American Group. 1997. Marine and industrial ropes. MIRC-1097 (general catalog). Ferndale, WA. 39p.

Torgersen, H. 2002. Service life of compacted steel wire ropes on varying block sheave diameters. Int. J. For. Eng. 13(1):51-56.

Williamsport Wirerope Works, Inc. 2000. General purpose catalog (Bethlehem Wire Rope). Williamsport. PA. 40p.