APPLICATIONS OF SYNTHETIC ROPE FOR IMPROVED ERGONOMIC, ECONOMIC AND ENVIRONMENTAL PERFORMANCE IN MOUNTAINOUS LOGGING

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ABSTRACT
Applications of a synthetic fiber (Ultra High Molecular Weight Polyethylene, UHMWPE) rope as a replacement for steel wire rope in mountainous logging operations are presented. Past and ongoing research has shown ergonomic gains and other operational effectiveness with its use. This paper presents research results, potentials, and issues in improving economic performance of ground based, cable based, and hybrid systems for harvest operations in both industrialized and non-industrialized harvest settings. Realizable social and environmental benefits are discussed. This area of research, its foundations in the wire rope and cable harvesting research of the 1960's and 1970's (one of the foundations of the Pacific Northwest Skyline Symposium / International Mountain Logging Conference) will advance the field with 21st century materials and applications. The research is funded by Oregon Occupational Safety and Health Administration grants to redesign worksites for employees.

KEYWORDS: fiber ropes, harvesting, line logging, cable logging

INTRODUCTION

The potential for rope constructed of ultra high molecular weight polyethylene fibers (UHMWPE AmSteel® Blue 12 strand braided rope[1]) to replace steel wire rope in logging applications has been shown at the 11th meeting of the International Mountain Logging and Pacific Northwest Skyline Symposium (Pilkerton, et al., 2001) and elsewhere (Garland, 2001; Garland, et al., 2003). The rope's strength is similar to steel wire rope of the same nominal diameter, but only about 1/9th the unit weight (Figure 1). The Oregon Occupational Safety and Health Administration funded grants to evaluate synthetic rope for ergonomic improvements for employees in the logging industry.

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

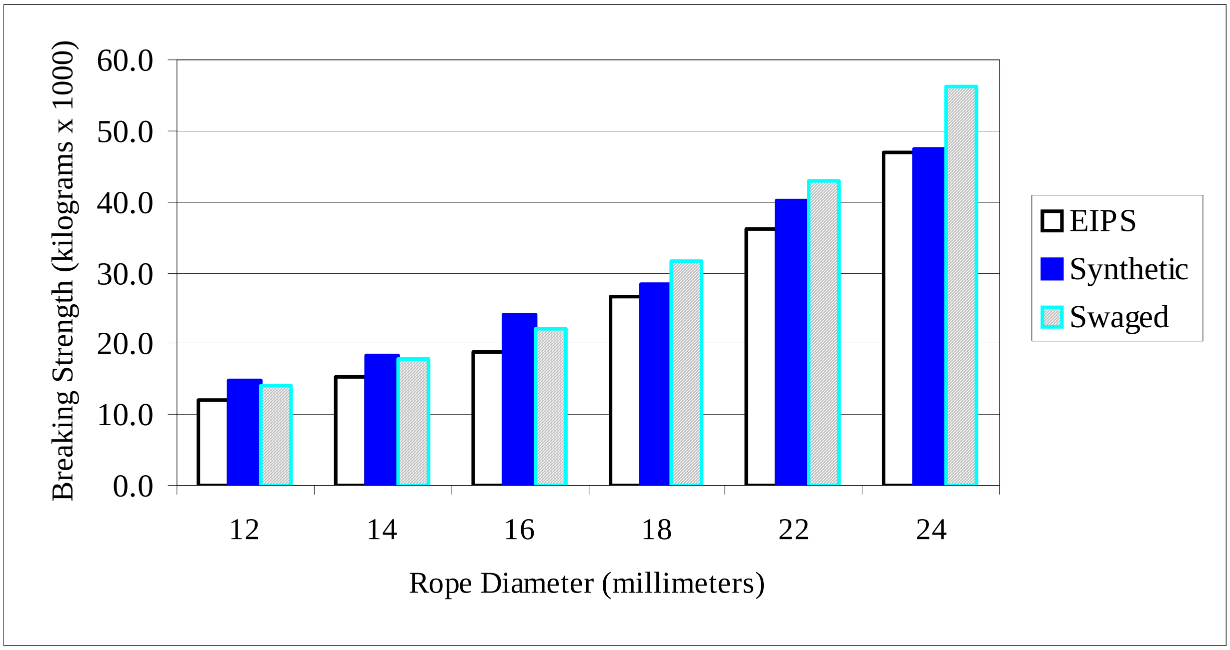

Figure 1. Ultimate breaking strengths of common diameter ropes used in logging applications: comparison of steel wire rope with AmSteel® Blue (UHMWPE) synthetic rope.

Logging is one of the most difficult jobs in terms of workloads and cardiovascular demands (Durnin and Passmore, 1967). Synthetic rope offers potentials to lighten workloads in various aspects of logging. Canadian researchers recognized the potentials of synthetic mainlines on skidders and investigated abrasion and strain generated by mainline choker sliders (Golsse, 1996; LaPointe, 2000). Research demonstrated ergonomic benefits and operational effectiveness are reported for uses as static lines in cable yarding (Leonard, et al., 2003) and skidder winch lines (Pilkerton, et al., 2003; Pilkerton, et al., 2004).

The obvious lower weight per unit of length and lack of stored torsional energy (imparted in manufacturing) are significant differences from steel wire rope. Thus synthetic rope may be pulled more easily over difficult terrain and logging slash, reduces fatigue, and possibly reduces slips and falls. Synthetic rope also does not produce “jaggers”, eliminating puncture wounds and lacerations. An Oregon logging contractor recognized the potential and installed a synthetic winch line because of OSU’s research efforts (Crouse, 2003) and now more than forty logging contractors are using synthetic ropes.

This paper presents results findings on applications of synthetic rope for improvements in ergonomic, economic, and environmental performance of logging operations.

STUDY DESCRIPTIONS

Skidding Winch Lines

A series of operational trials have been conducted with ground skidding operations in Oregon. These included:

- An eastern Oregon contractor using a Caterpillar D6C-10K crawler tractor (105 kW; 13,900 kg) outfitted with a Carco F50 integral arch winch. The terrain was broken, and slopes exceeded 30 percent in some areas. The contractor typically spooled 23 meters of 22-millimeter swaged steel wire rope. For this trial, 36 meters of 22-millimeter AmSteel® Blue rope was installed. The operator typically drove to logs, pulled the winch line, and set pear-ring and toggle chokers to the logs. Turns usually consisted of three to four logs.

- A western Oregon contractor used a John Deere 650G crawler tractor (68 kW, 8600 kg) with a JD 4000 series integral arch winch. The terrain was uniform, with slopes to 30 percent. Thirty-eight meters of 16-mm AmSteel® Blue rope was installed with a round-ring and toggle choker system. The operator drove to the logs and collected three to four logs per turn.

- The OSU Forest Engineering Department Student Logging Program utilized a John Deere 540 B rubber-tired skidder (68 kW, 7600 kg) to thin 40-50 year old Douglas-fir stands on slopes less than 20 percent. Thirty-eight meters of 18-mm AmSteel® Blue rope was used with a round-ring and toggle choker system. Skidder operators set their own chokers or collected preset turns of three to four logs hooked by a choker setter.

- A non-industrial trial was conducted with a small woodland owner using a Farmi JL 351 winch system mounted to the Power Take-Off (PTO) of a John Deere 5210 farm tractor. The owner/operator was using three Farmi slider chain chokers with a grab hook at the end of the steel winch line, for a total of four chain chokers. The 8-mm steel line was replaced with a 9-mm AmSteel® Blue winch line. A prototype synthetic choker was constructed with 0.3-meter lengths of chain at each end of a 9-mm diameter synthetic rope section and using a Farmi winch line slider as the choker bell (Figure 2). The operator set two to three logs per turn and winched them to a designated skid trail.

Figure 2. Prototype log choker using chain, synthetic rope, and a Farmi slider hook for a choker bell to replace chain choker.

Cable Yarding Applications

Three Oregon cable yarding logging contractors participated in trials using synthetic ropes as static lines in place of traditional steel cables. The applications included:

- tailtree and intermediate support tree guylines,
- intermediate jack support lift line,
- rigging straps, and
- tower guyline extensions.

The OSU Forest Engineering Department Student Logging Program also implemented synthetic lines in the applications listed above. In addition, the 9-mm steel mainline of the Koller K300 yarder was replaced with 9-mm AmSteel® Blue rope in the summer of 2002. The nominal spooling capacity of the mainline drum is specified by the manufacturer to be 325 meters (for steel wire rope). Approximately 395 meters of synthetic rope was spooled on the drum, with the potential for additional spooled length because of flange distance remaining.

STUDY METHODS

Ergonomic

In the Summer and Fall 2000, field trials were conducted with the OSU Forest Engineering Department Student Logging crew on the OSU McDonald-Dunn Research Forest north of Corvallis, Oregon. Heart rate and subjective evaluation data were collected to evaluate the physiological and psychological response between using traditional steel wire rope and synthetic 12 strand braided AmSteel® Blue rope (Samson Rope Technologies, 2003) in logging with a skidder winch line.

The study group was comprised of two females and five males. Ages ranged from 20 to 47 years, averaging 29 years. All participants self-rated their physical fitness as "Good" and free of physical limitations prior to the trials.

A John Deere 540B rubber-tired skidder with a winch drum and swing boom arch grapple was used. The winch line ("bull" line) on the skidder was either a 14-mm swaged IWRC steel wire rope or an 18-mm 12-strand braided synthetic rope. Each worker pulled the bull line and set a choker for a series of five turns. Distances (3-30 meters), slope percent (-55 to +52), and uphill/downhill were randomly assigned for each turn.

Heart rate data were collected using the Polar Advantage® monitoring and recording system (Polar Electro Oy, 1998). Heart rates (beats per minute, bpm) were recorded every five seconds. The time to complete each task element was compiled from the recorded heart rate – time relations created with data markers applied by pushing a button on the wristwatch style data logger.

Economic

Short duration time and motion studies were conducted in addition to the time-task relations gathered from the heart rate monitoring device.

RESEARCH FINDINGS

Ergonomic

Analysis of the heart rate and time relationships for the various task trials consistently showed the following:

- lower heart rates,
- faster completion of tasks, and
- reduction in the time required for the heart rate to return to initial (pre-exertion) rate with synthetic rope.

For a 24-year old operator pulling the 18-mm synthetic winch line and setting his own chokers, 80 percent of the time the work is in the heavy or more strenuous Rodahl work intensity categories (Figure 3).

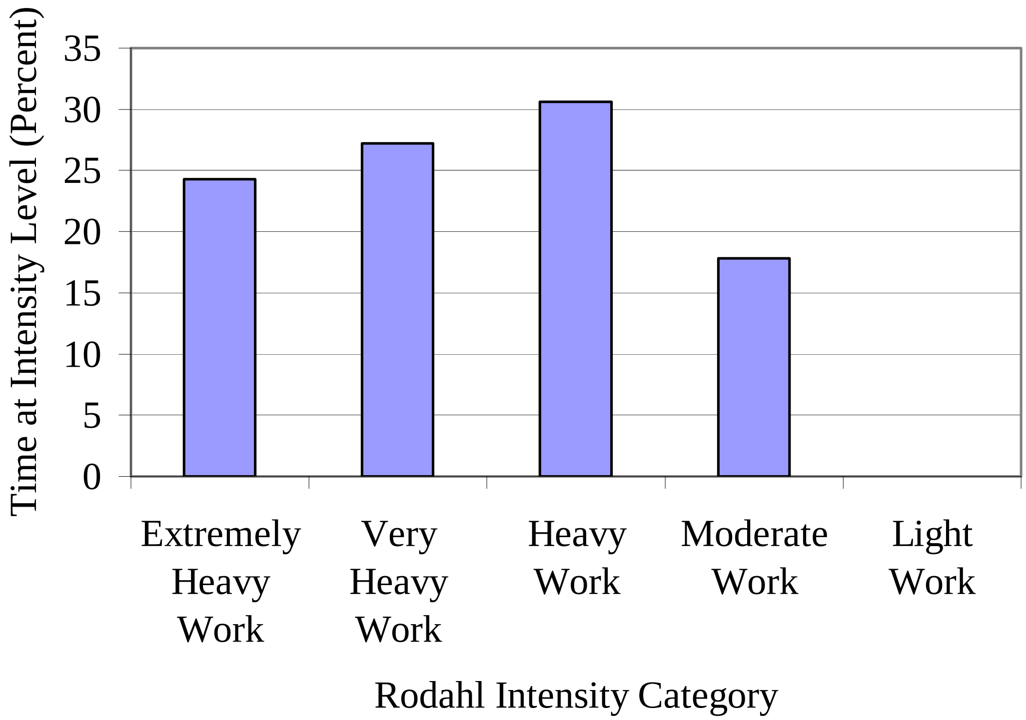

Figure 3. Heart rate exertion intensity, percent time by Rodahl categories, for a 24 year-old male pulling an 18-mm synthetic winch line.

A standing, at rest, heart rate of 70 bpm was assumed for all individuals. Heart rate exertion intensity zones (average person, 20-30 years of age) can be described as follows (Astrand and Rodahl, 1986):

Heart rate (bpm)	**Exertion Level (onset of)**
< 90	Light Work
91 - 110	Moderate Work
111 - 130	Heavy Work
131 - 150	Very Heavy Work
151 - 170 +	Extremely Heavy Work

The outhaul (pulling line to the logs) element was the focus of the difference in rope type. Heart rates, on average, were statistically similar. However, task time was 0.5 minutes faster with the synthetic rope. However, heart rates are 70-85 bpm higher than the initial heart rate of 70 bpm. Heart rates increased 10 – 15 bpm with sustained activity (over the first turn) during the five-turn sequence. Analysis of Variance showed significant differences in mean heart rate for rope types and gender (main effects) and slope gradient, distance pulled, uphill/downhill (covariates).

Economic
Increased productivity of 10 percent, on a daily basis, is projected from the initial results of the skidder winch line trials for operators setting their own chokers. Coupling this result with a recent skidder productivity study (Kellogg, et al, in review), an additional 4 turns per day could be realized on a unit with 120 – 150 meter skidding distances. While log and turn size are important factors, additional volume production could be about 6 cubic meters (1000 board feet, 1 Mbf) per day, at a benefit of US$ 50 – 100 per day to the contractor.

Anecdotal evidence from contractors suggests they would pull additional distances rather than take time to position the machine closer. The eastern Oregon operator, pulling the largest of the trial winch lines, stated a savings of 10 minutes on a single turn at full line length up an adverse slope. Further designed studies should document these differences. Two contractors spliced additional synthetic rope onto their winch lines, whose initial length was based on their steel winch line. Increasing winch line length suggests additional costs are covered by the additional benefit of increased productivity. One contractor, independent of our studies, stated a cost of US$1.00 per operating hour for his synthetic winch line (Schlatter, 2004) and gains much more by its use.

Non-quantified time savings were also evident in the reduction of delays associated with "spronged" steel winch lines (at moment of free spool release), slow inhauls to prevent improper spooling, and/or the clearing of a stuck winch line. Synthetic winch lines show consistent spooling and lack delays associated with using steel.

Reductions in time and physical effort associated with transporting rigging (straps, blocks, and guylines) have been reported as well. The Hooktender (rigging person) can make one trip to the next lift tree with all the synthetic gear on a packboard, as contrasted with 3-4 trips previously. This same operator has successfully used a synthetic skyline extension (not for carriage travel) noting ease of manual layout, no need for mechanical power to assist in road changes, and a reduction in rigging time.

Social And Environmental Benefits
Timber harvesting work has a reputation for being "difficult, dirty and dangerous" compared to work in urban occupations (Garland, 2001). At the same time, financial benefits, autonomous work environments, and the satisfaction of overcoming challenges seem to compensate in part for the negative aspects of forestry work. Using new technologies like synthetic rope to reduce workloads is seen as a positive move to consider workers' health and safety. Several benefits can be seen:

- new recruits to the sector see lighter workloads in entry-level tasks,
- existing workers see a shift to lighter materials as a firm's commitment to their well-being, and
- the accumulated knowledge base of older workers in key positions may be extended if the workloads are more in line with capacities of older workers.

While new technologies cannot fully compensate for negative aspects of forest work (steep terrain, weather, job hazards, etc.), synthetic rope offers a positive statement and result for forest workers.

Improvements in environmental performance with respect to ground-based skidding activities are also likely. Ewing (2003) reports on the reduction of machine travel into riparian zones with the use of a synthetic mainline. Guidelines for minimizing area impacted by skid trails are dependent on operators pulling winch line a designed distance. In practice, steel wire rope is a physical and mental barrier to achieving desired lateral outhaul distances. Synthetic mainlines increase the likelihood of meeting environmental objectives. The use of synthetic mainlines could reduce operational restrictions put on harvest activities, avoiding the need for more expensive systems to achieve the resource protection and stand management objectives. For example, a skidder winch line may be manually pulled down a short, steep slope and the logs "long-lined" to the landing. This eliminates setting up a cable system road. Typically these short corners are yarded in less time than required for rigging and de-rigging of the cable road. Hourly machine rates for a skidder are a fraction of those for a cable yarder.

FUTURE RESEARCH

Upcoming research includes the evaluation of a synthetic line for use as a skyline. Initial trials will be performed to empirically determine the mechanical stress / strain relationships for incorporation into cable payload programs such as LOGGERPC (Jarmer and Sessions, 1992). LOGGERPC 4.0 is a 21st century tool resulting from the wire rope and cable harvesting research conducted in the 1960's and 1970's. This area of research formed the basis for Pacific Northwest Skyline Symposium and International Mountain Logging conference series. Small log operations for thinning and fuel reduction will be conducted with small diameter synthetic rope and small winching systems. New rope types will also be investigated for specific applications in logging.

SUMMARY

Beneficial improvements are possible with the introduction of synthetic rope as an alternative to steel wire rope winch lines, static lines, and other cables. These include reduced physical impact on workers, productivity improvements, and reduced environmental impacts. Synthetic winch lines have been well received by contract loggers using them. Application of synthetic ropes to harvesting activities are increasing, as evidenced by the number of operators independently trying them as a result of the OR-OSHA worksite redesign grant research. These loggers are creating other innovative applications of synthetic rope including chokers, running lines, truck wrappers for load securement, and many not yet identified.

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