COMPARISON OF ERGONOMIC PERFORMANCE FOR A SKIDDER OPERATOR USING STEEL WIRE AND SYNTHETIC ROPE WINCH LINE

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ABSTRACT - The use of a synthetic fiber (Ultra High Molecular Weight Polyethylene, UHMWPE) rope as a replacement for steel wire rope winch line on a rubber-tired skidder for logging operations is presented. Past and ongoing research shows ergonomic gains and other operational effectiveness. Paper presents research results on work effort required for operators setting their own chokers. Differences in heart rates, and task times are compared. Increased productivity with the synthetic winch line is estimated. Subjective evaluations by trial users are summarized. Potential social and environmental benefits are discussed. Benefits include tradeoffs from improved technology to reduce operational restrictions and operational costs. The research is funded by Oregon Occupational Safety and Health Administration grant to ergonomically redesign worksites for employees.
KEYWORDS: fiber ropes, harvesting, line logging

INTRODUCTION

The potential for rope constructed of ultra high molecular weight polyethylene fibers (UHMPWE AmSteel® Blue 12 strand braided rope[1]) to replace steel wire rope in logging applications has been shown at previous COFE meetings (Garland et al., 2001; Pilkerton 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. The Oregon Occupational Safety and Health Administration funded grants to evaluate synthetic rope for ergonomic improvements for employees in the logging industry.

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 ways for logging (Pilkerton, et al., 2001). The obvious lower weight per unit of length and lack of stored torsional energy are significant differences to steel wire rope. Thus, the rope may be more easily pulled over difficult terrain and logging slash, reduces fatigue, and possibly reduces slips and falls. Synthetic rope also produces no "jaggers", eliminating puncture wounds and lacerations. Canadian researchers recognized the potentials of synthetic mainlines on skidders and investigated abrasion and strain generated by mainline choker sliders (Golsse, 1996; LaPointe, 2000). An Oregon logging contractor recognized the potential and installed a synthetic winch line because of OSU's research efforts (Crouse, 2003).

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

This study reports on the first operational trial of operators setting their own chokers behind a rubber-tired skidder using a synthetic winch line. Additional research was conducted to evaluate physical workloads through heart rate and recovery times for this activity and its elements. Subjective comparisons were solicited and recorded.

STUDY METHODS

In the Summer and Fall 2000, field trials were conducted with the OSU Forest Engineering 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 emotional 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 2 females and 5 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.

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 9/16-inch swaged IWRC steel wire rope or a ¾-inch 12-strand braided synthetic rope. Each worker pulled the bull line and set a choker for a series of 5 turns. Distances (10 – 99 feet), 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 5 secs. Time to complete task elements were compiled from the recorded heart rate – time relations based on data markers applied by pushing a button on the wristwatch style data logger.

After each trial, the worker completed a subjective evaluation form to rate the effort required for a given task and rope type in comparison to the base task. The base task for the skidder trial was pulling a 150 feet of 5/8-inch steel wire rope (111 pounds) 300 feet on a gravel road of 4 percent grade. The forms had a linear scale, with midpoint being the "Same" effort comparatively. The left endpoint was labeled "Extremely Easy" and the right endpoint labeled "Extremely Difficult". The linear difference between marks was recorded as a unit less value measured from zero (extremely easy) with an engineers scale.

RESULTS

Field Trials

Figure 1 shows a sample trend of the heart rate data record for steel and synthetic ropes for 5 turns each. Turn outhaul (pull to log) distance, slope, and uphill/downhill variables are not consistent for steel and synthetic. Peaks generally correspond to end of line pulling element. Figure 2 shows the heart rate exertion levels for a 24 year old male for pulling a ¾-inch synthetic winch line. Eighty percent of the time the operator's work intensity is in the heavy work or more strenuous categories.

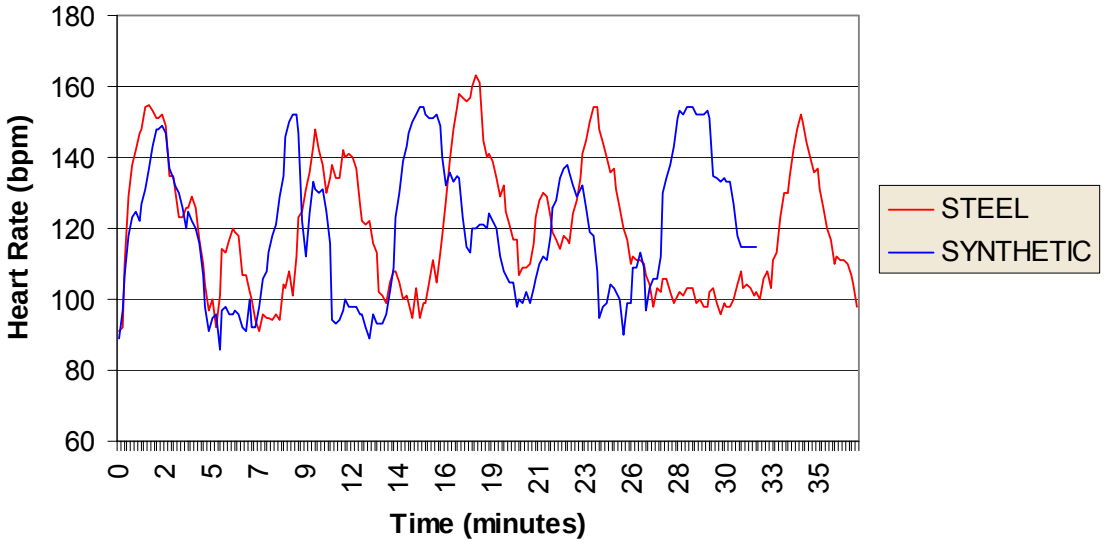

Figure 1. Heart rate traces as a function of time for 5 turn cycles. Elements include lateral out (pull to logs), hook, return to skidder, winch in, and unhook.

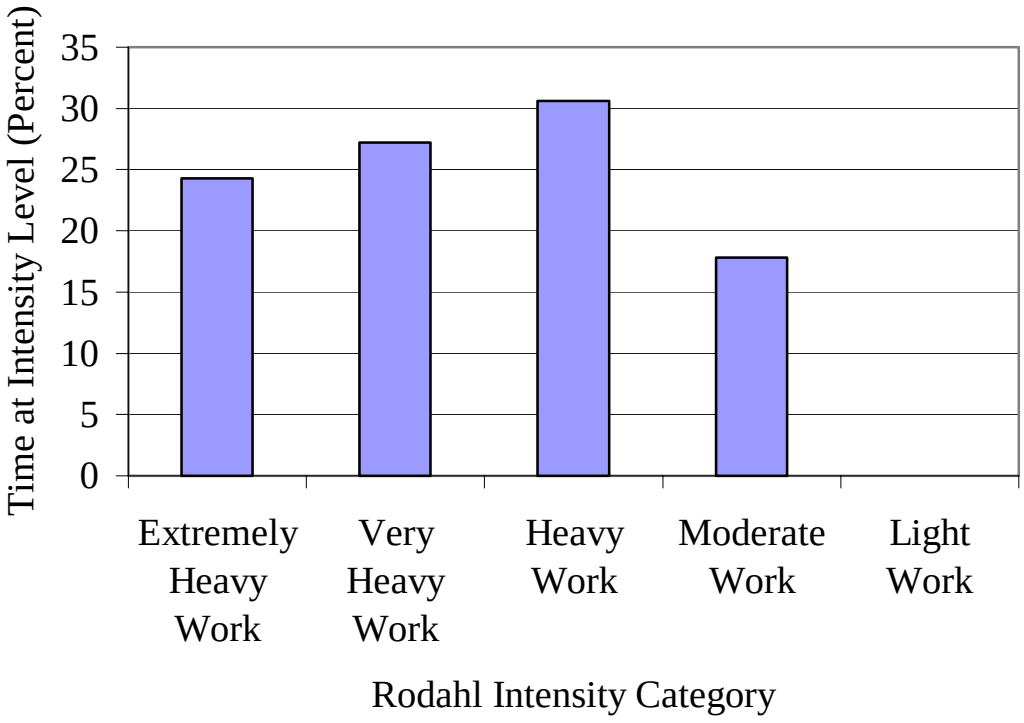

Figure 2. Heart rate exertion intensity, percent time by Rodahl Categories, for a 24 year old male pulling a ¾-inch synthetic winch line.

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 reader should be cautioned to keep these values in mind when reviewing the results. The initially tendency is to think of a 15 bpm difference as small. However, this represents a 20 percent increase over the standing at rest rate. A 15 bpm increase can move an individual from one exertion level to the next.

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 (Figure 3). Heart rates were lower for all elements when using the synthetic rope. There appears to be an exertion carry-over effect into the next element, ie, when hooking the turn. This activity occurs right after the line pulling element (outhaul).

Still 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 5 turn sequence. ANOVA analysis showed significant differences in average heart rate for rope types and gender (main effects) and slope gradient, distance pulled, uphill/downhill (covariates).

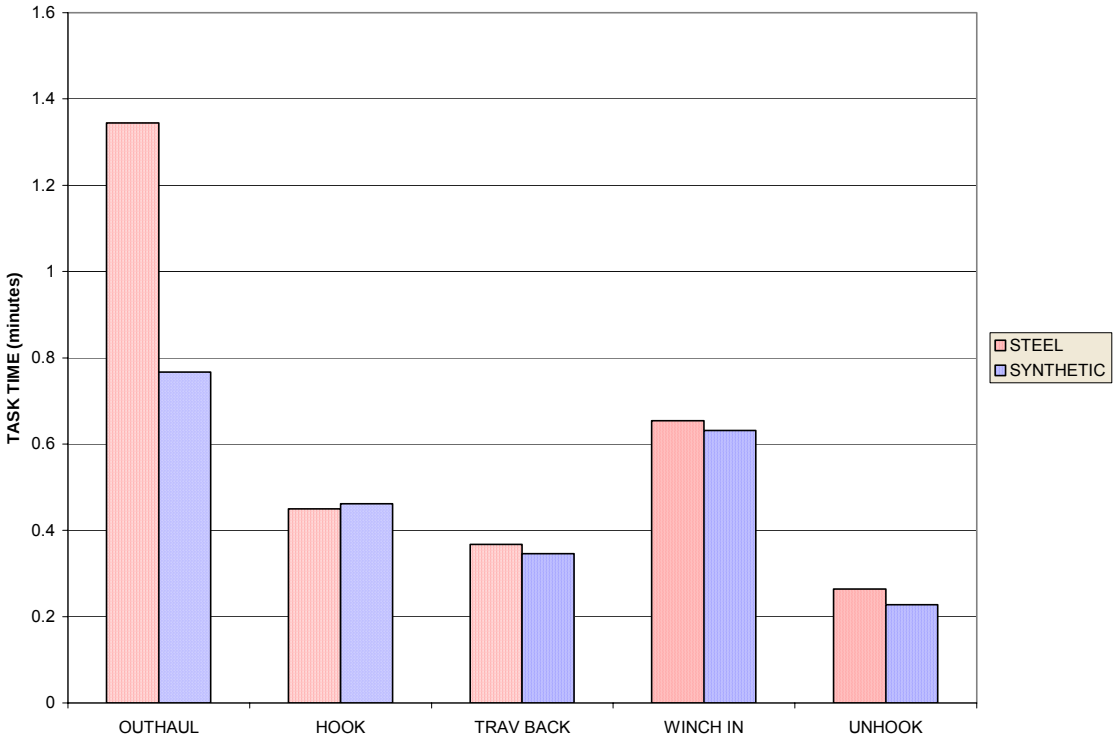

Figure 3. Average skidding task times by activity element for all 7 worker's series of 5 turns for steel and synthetic winch lines.

Subjective Analysis
Evaluated numerically, synthetic rope was subjectively considered 20 percent easier downhill and 15 percent easier uphill when pulled off the skidder bull winch (Figure 4). A t-test on the mean subjective values failed to show a statistical difference in the ratings. Analysis of Variance showed a statistical difference by slope and gender.

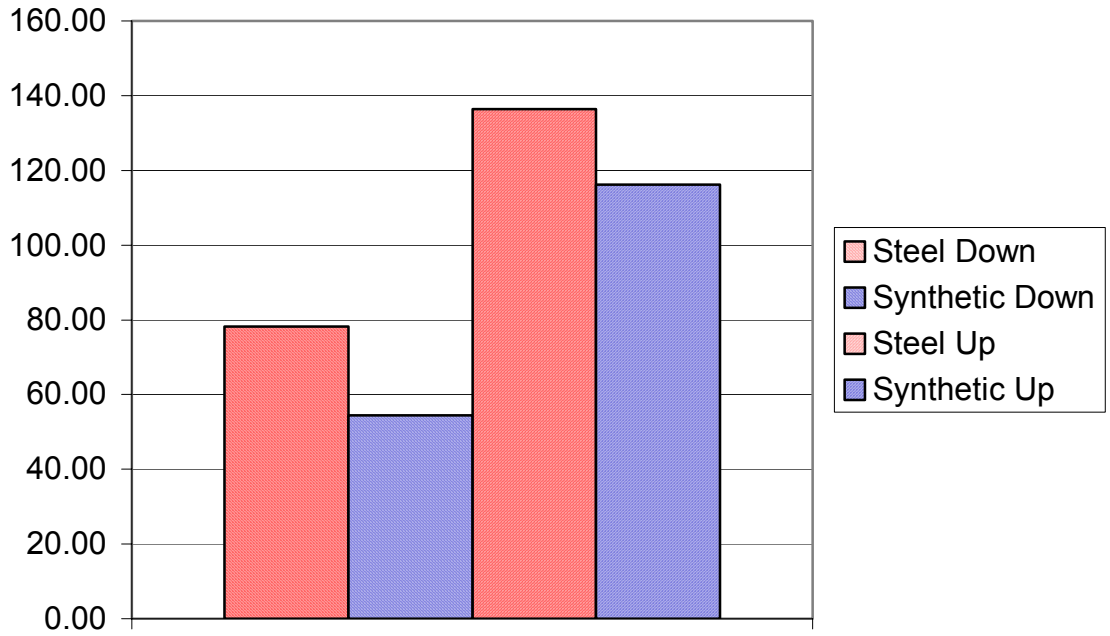

Figure 4. Average (n=7) subjective rating for steel and synthetic skidder winch line pulling. Scale is unit less, relative response to base case task, where zero is considered "extremely easy".

Numeric results of the subjective analysis are informative, but the worker comments are also interesting. Negative comments noted tendency for synthetic rope loops to catch on slash. Overall, synthetic rope was well received, especially by those who have cut their hands on a jaggered steel cable. Not surprisingly, the subjective views of the workers favor synthetic rope over steel wire rope. Recorded observations include:

- "Much easier, almost the same as just walking without anything."
- "Hardly like pulling anything."
- "Felt like leading a good horse."
- "Both directions were easier than dragging cable (steel, sic) on road."

DISCUSSION

Differences in heart rates were not readily evident for several possible factors. First, there was a wide variance with the data for 5 turns of different distances, slopes, and direction (up/down). Secondly, the thin and ravelly soils, coupled with thick slash, made outhaul traversing physically demanding. The third factor, malfunctioning of the free spool, was suspected during the trial and verified afterwards.

Mechanical difficulties of the skidder winch to free spool (made obvious using the synthetic rope) likely also affected the statistical perception on ease of use. This likely affected the perception of the effort required for the steel winch line as well. After the study, the winch was dismantled. The clutch packs in the winch had been damaged and caused the inability of the drum to free spool properly.

This led to the development of alternative methods of pulling the line off the winch. The typical method with steel is to grab the line, lay it over the shoulder, and use the leg driven upper body to pull line to the logs. The synthetic rope could be easily pulled off the drum, coiled or piled on the ground at the back of the skidder for the approximate distance out to the logs. The operator then would walk out pulling the slack rope to the logs. One potential negative comes from this technique. The operator would no longer put the rope on the shoulder (upper body technique), but rather pull the rope along behind like pulling a rolling suitcase. This could create arm / upper shoulder injuries if the rope snagged and sharply pulled the arm rearward. We observed the potential, but did not experience injuries.

Other cooperators using synthetic rope as a winch line experienced similar drum free spooling difficulties. The primary reason is the “free spool adjustment” is set tight (high resistance to free spool) to minimize the tendency of steel wire rope to release the potential energy stored on the wrapped drum. The wire rope expands beyond the wrapped position, sometimes spronging wildly if pulling motion is stopped suddenly and the drum has rotational momentum. This creates a misalignment of the rope on the drum, like the backspooling of a fishing reel. Delays are associated with improper spooling. Failure to properly spool the steel line generally results in a stuck line the operator can not pull off by hand. To free the line, it must be attached to a stump or tree, and then the skidder is driven ahead to pull the line free.

The cooperators have experienced few, if any, spooling problems or hang ups with synthetic winch line. Most cooperators adjusted the free spool mechanism to a low resistance for the synthetic rope which does not expand on the drum. Productivity gains are likely experienced with the reduction of improper spooling and/or the elimination of a stuck winch line.

Increased Productivity

Gains in effectiveness can offset the costs of synthetic rope at current prices. For example, based on initial results from the skidder winch line trials (5 turns per worker), it is projected a 10 percent increase in productivity on a daily basis might be possible for a single machine operator setting his own chokers. Coupling this result with a recent skidder productivity study (Kellogg, et al, in review), this could amount to an additional 4 turns per day for 400-500 foot skidding

distances. While load size is an important factor, this could be about 1000 board feet (1 Mbf) additional production per day, at a benefit of $ 50 – 100 per day to the contractor.

Anecdotal evidence from contractors suggests they add additional distance to their line pulling rather than taking time to position the machine closer. 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.

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
- 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 for 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 laterally a designated distance. In practice, steel wire rope is a physical and mental barrier to achieving desired lateral outhaul distance. Synthetic mainlines increase the likelihood of meeting environmental objectives. The use of synthetic mainlines could reduce operational restrictions put on operations, avoiding the need for more expensive systems to achieve the stand management objectives.

SUMMARY

Beneficial improvements are possible with the introduction of synthetic rope as an alternative to steel wire rope winch lines. These include reduced physical impact on workers, productivity improvements, and reduced impact logging. Synthetic winch lines have been well received by contract loggers using them. Application of synthetic ropes to harvesting activities are significantly increasing, as evidenced by the number of operators independently implementing them as a result of the OR-OSHA worksite redesign grant research. These loggers are looking for other innovative applications of synthetic rope including chokers, running lines, truck wrappers for load securement, and so forth.

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