Is Light Right?

Safe Highlines With Minimal Gear

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Introduction

As high-angle rescue techniques evolve, new equipment allows us to build safer, more easily rigged systems. Unfortunately, this comes at the cost of weight and space savings, as we need more tools and devices in our packs. From a USAR standpoint, this isn't as pressing an issue, as the equipment is hauled relatively short distances. In the mountains, however, weight savings can drastically improve response time and efficiency.

Highlines are considered one of the more gear-intensive and advanced systems used in rescue. The obtuse angles involved in the rigging have the potential to drastically increase resultant forces on the anchors, and thus demand a complete understanding of many rigging theories and smaller systems. Unfortunately, many of the techniques and rules-of-thumb in highline rigging are in use because they "haven't failed yet," and not through careful analysis. Many of those techniques are perfectly sound, but others are questionable. Stephen Attaway and Marc Beverly highlighted several questionable practices in their paper on forces in highlines, specifically the use of tandem Prusiks as the sole anchor for tensioned track lines (Stephen W. Attaway, 2013). It was shown that the static safety factor of Prusik-anchored systems was significantly lower than desired, and the recommendation was made to use full-strength bollard tie-offs.

While many safety concerns can be alleviated with the use of more equipment, such as employing pinned carriages as bollards, more equipment means more weight to carry. In this paper, an alternate track line anchoring system is investigated, as well as the potential for weight savings in other areas of highline rigging.

Anchors

In a paper presented at SARCON entitled "Go Light, Go Fast," the strength and usefulness of Dyneema slings as anchors was analyzed. It was found that when used correctly, Dyneema had the potential for significant anchor strength and weight savings. Several anchor configurations with Dyneema slings tested at over 30kN failure strengths, while still remaining easy to de-rig and re-use. Dyneema is significantly lighter than nylon webbing and rope, though at a slight loss in versatility and increase in price. The space savings of Dyneema materials is extraordinary, however, and much greater lengths can be packed in very small spaces, with insignificant losses in material strength. Three Dyneema anchor configurations that exhibit obvious usefulness in highlines are a three-leg anchor with a tied masterpoint, a basket hitch, and a wrap-two-clip-four.

Basket Hitch – Mean Strength: 45 kN

Three Leg Masterpoint – Mean Strength: 30kN

Wrap 2 Clip 4 Construction

Wrap 2 Clip 4 – Mean Strength: 64kN

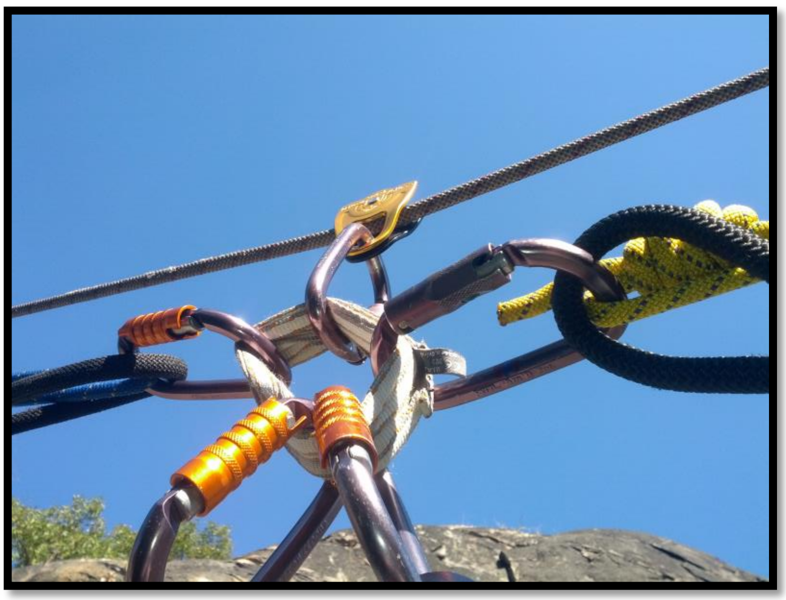
Track Pulleys and the Collection Point

One of the most popular pulleys for use in highlines is the Kootenay style, with a large diameter sheave, and large area between the sideplates. Most of the pulleys of this style also include several rigging attachment points, allowing the use of the pulley as the collection point. The wide sheave makes for easy use in twin-track highlines, as it feeds multiple ropes well. Unfortunately, Kootenay carriages take up much more space than a standard Prusik-minding pulley, and have limited usefulness in other pulley applications due to their size.

When rigging a single-track highline, a standard single-sheave pulley will work as a track carriage, but requires an attached collection point for multiple connections. A rigging plate will work for collection, but represents a weighty device that may not generally be part of a mountain rescue team's kit.

In place of the pulley and rig plate combination, a collection point may be constructed with two 30 or 60 cm Dyneema slings. The use of two separate slings preserves redundancy, and the doubled or quadrupled nature of the individual strands creates an extremely strong connection. The slings are lighter than a metal collection point, and are versatile and easy to use. The single-sheave pulley is an item that also has usefulness outside of the highline, while remaining light and strong.

The drawbacks to this system are a loss in knot-passing ability, and the inability to use more than one track line. Given spans that are less than the largest rope length available, and using the control lines as an unloaded backup, these concerns are addressed.



Lowering Devices

Control lines require a descent control device to pay out rope while the highline is traversed. Depending on the angle of decline in the track line, the device may take a significant portion of the load. If the track line were to suffer a catastrophic failure, the device and control line anchor could experience significant shock loading as the load transfers completely to the control lines.

Standard descent control devices are often used, including brake racks, scarabs, I'Ds, and MPDs. While these devices work, they are heavy and take up space, and in many cases are not tools that a mountain rescue team may have.

A reasonable alternative to a descent control device is the Monster Munter hitch. It is related to the Munter hitch and provides a significant increase in friction to the standard Munter. Testing was done on the dynamic load-catching ability of the Monster Munter when backed up with a Prusik hitch on the brake line. The Monster Munter was found to have passed the BCCTR Belay Competency Drop Test, showing that it can handle significant shock loading. The major benefit of the Monster Munter is the minimal gear required - only a large carabiner for the hitch and a Prusik for backup. It is easily tied behind a pig-rigged raising system, and can be transferred in and out of the system fairly quickly.

The Monster Munter does require some experience to tie, but is a highly versatile hitch that has applications beyond highline control systems. Within the highline realm alone, it can also be applied to control of reeving lines, and de-tensioning track lines during breakdown.

Track Line Anchoring

As J Marc Beverly and Stephen Attaway's paper described, relying solely on tandem Prusik hitches for a track line anchor can drastically reduce the static safety factor of the highline. The belief that when overloaded Prusiks will gradually slip enough to reduce the catenary angle, and thus the anchor forces, was shown to be erroneous, as the amount of Prusik material melted would result in probable failure. Recommended alternatives were use of a pinned carriage as a bollard or a tied off I'D or other large descent control device (Stephen W. Attaway, 2013).

Considering the added weight of bollards or other DCDs for the track line anchors, a suitable alternative was sought that would have reduced weight and gear requirements.

Question

Can ropes be anchored using Prusik cords and carabiners in such a way that they retain over 80% of the rope strength, while remaining reusable under normal loading conditions?

Materials Used

The material used was provided by Sterling Rope. Two different rope sizes were used - ½ inch and 7/16 inch. The half-inch rope was the Sterling SuperStatic2, with a published breaking strength of 41.2kN. The seven-sixteenths rope was the Sterling SafetyPro, with a published breaking strength of 32.5kN, and a published figure-8 knot breaking strength of 23.4kN. Both ropes are made completely of nylon, with kernmantle construction, and low-elongation properties.

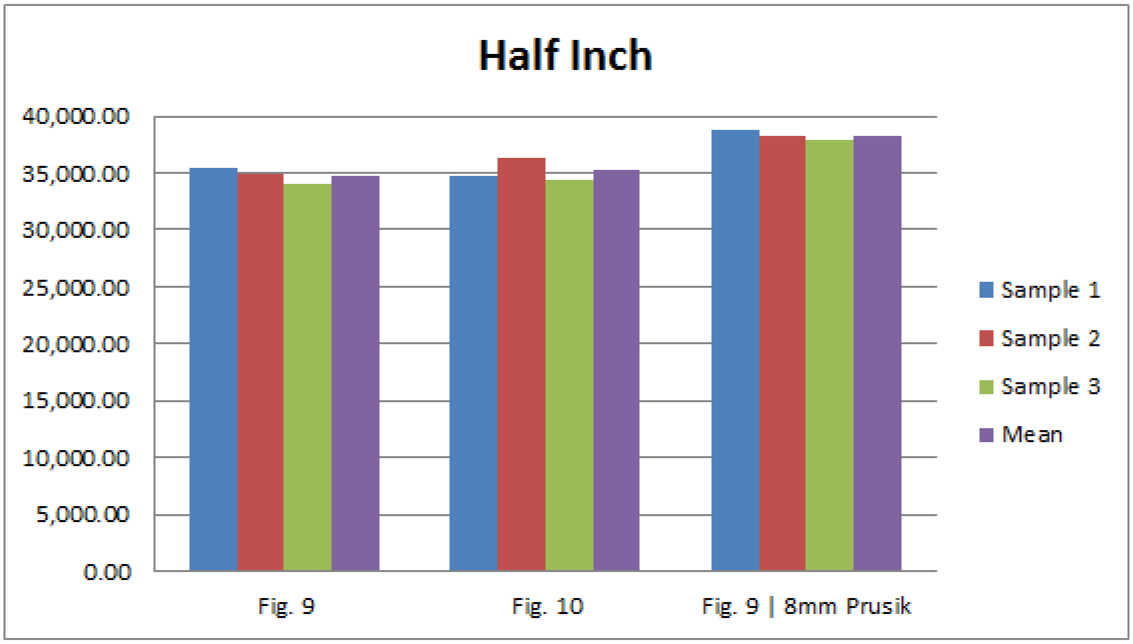
Testing

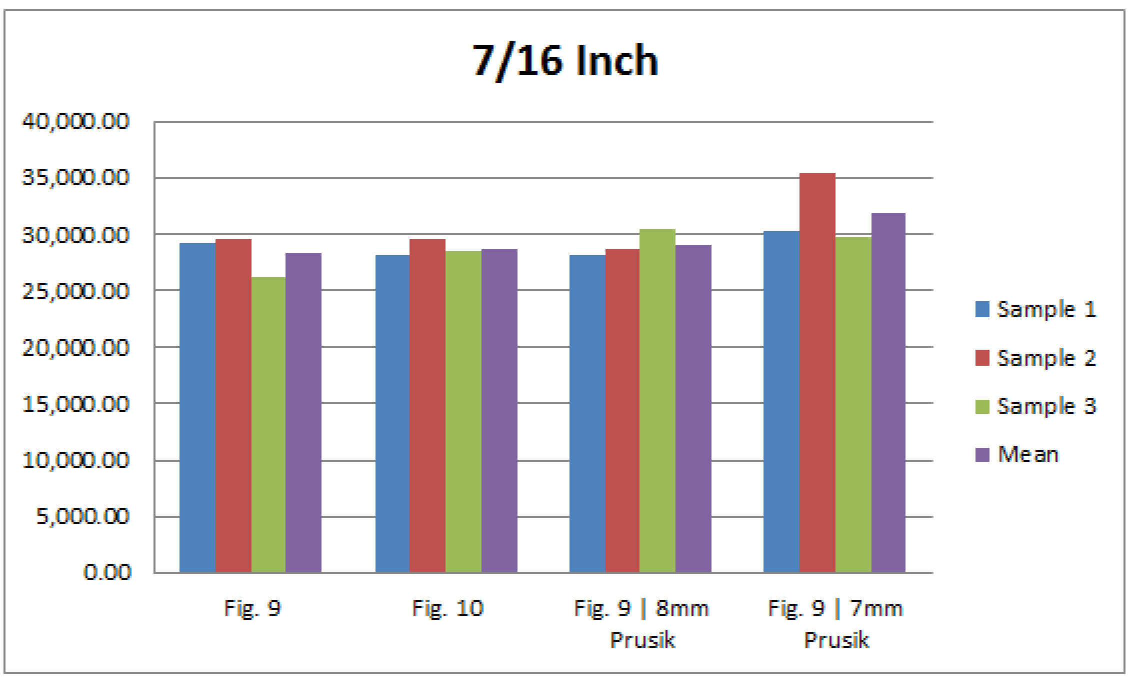
Several tests were performed, all on an Instron Tensile Tester, with a 100kN load cell. The tests were:

- Half-inch rope
  - Figure-9 knot
  - Figure-10 knot
  - Figure-9 knot with 8mm Prusik before the knot
- Seven-sixteenths rope
  - Figure-9 knot
  - Figure-10 knot
  - Figure-9 knot with 8mm Prusik before the knot
  - Figure-9 knot with 7mm Prusik before the knot

The Prusik tests were arranged such that the Prusik was placed three inches before the knot, with the Prusik taking the load at first.

Results





The figure-9 knots gave a fairly high efficiency in the half-inch rope, with mean failure occurring at 34.7kN. In seven-sixteenths rope, the figure-9 broke around 28kN, which is significantly stronger than the published figure-8 breaking strength.

Figure-10 knots showed no appreciable strength increase, with failure around 35kN and 28.7kN in the half-inch and seven-sixteenths inch, respectively.

In the half-inch, the 8mm Prusik and figure-9 combination proved significantly stronger than any other tested termination method, with the average breaking strength at 38.3kN, which is approximately 93% efficiency.

In seven-sixteenths rope, the 7mm Prusik and figure-9 combination tested to a mean of 31.7kN, which was higher than the figure-9 and 8mm Prusik with figure-9 (29kN).

Failure in all samples was at the knot. The Prusiks appeared to slip at around 10kN, and Prusiks used in the testing showed no strength loss when pull-tested.

Conclusion

- Confirming previous statements to the affirmative, the figure-9 knot appeared to have a higher efficiency than all published efficiencies for the figure-8. If enough rope is available, the figure-9 is a stronger and more easily untied loop knot.
- The figure-10 did not add any appreciable strength beyond that achieved with the figure-9. If excess slack must be taken up, it is a viable knot, but there is no strength benefit associated with it.
- The Prusik and figure-9 combination proved to be the strongest end connection, with efficiencies on all tested samples above 90%. In 7/16 rope, a 7mm Prusik is advised.

Discussion

While none of the tested methods preserved the entirety of the rope's MBS, the Prusik and figure-9 combination tested very close. In applications involving high loads, such as track line tensioning, it appears to be a viable alternative to bollards or high-strength tie-offs. The major benefit of it is that the Prusik will slip at moderate loads (around 10kN in this testing), acting as a sign that high loading is becoming a factor. However, upon slight slippage, the knot will begin to share the load, drastically reducing the amount of Prusik material that is damaged. This solves the problem of tandem Prusiks eventually failing, and reduces the amount of equipment necessary to set up a safe track line. The Instron used did not have a long enough throw to test tandem Prusiks with a figure-9 behind them, but the author believes that this may have an even greater efficiency, and further testing is warranted.

Final Thoughts

While highlines are easily constructed with purpose-made equipment in a safe manner, both weight and space can be saved without compromising the safety of the rigging. The techniques described in this paper should not be immediately adopted by anyone, but rather tested and trained with before use. They are presented as options to help teams reduce the weight they carry on calls and to encourage experimentation and discourse on shifting towards lighter and faster rigging.

Bibliography

Stephen W. Attaway, J. M. (2013). *Track Lines and Guiding Lines: Forces Based on Point Loads in a Catenary.*