Abstract:

There have been many in-depth mathematical analysis of track line force at the anchor points in high line systems using calculations of pre-tension and track line sag. Using direct read instrumentation experiments, we applied varying amounts of pre-tension on various track line configurations pulling at the mid-span point with measured force to observe forces at the anchor points, the amount of slippage (if any) at the tensioning element / progress capture and the amount of deflection resulting in the track line.

Bio: Tom Pendley served as Deputy Chief of Operations, Training and Special Operations for the Peoria Arizona Fire Department, before retiring in 2016 after 26 years of Service. He taught technical rescue for the Phoenix Fire Department for 15 years and was a technical rescue instructor trainer for the Arizona State Fire Marshals Office for 10 years. Tom served 14 years as a volunteer with the Maricopa County Sheriff's Mountain Rescue Team including 5 years as team commander. Tom has authored dozens of articles on rescue technique and training for Fire Rescue Magazine and other publications. Tom has conducted a number of informal back yard tests on rescue systems over the years. He holds a helicopter private pilot rating and is an avid mountaineer, river runner and powered paraglider pilot. Tom now works full time at the helm of Desert Rescue Research, which specializes in developing high quality technical rescue training resources. He currently lives with his family in Port Townsend, Washington.

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Slow Pull Testing of Track Line Tensioning Systems Used in High Line Systems.

By Tom Pendley

When pre-tensioning high lines, I was taught and have used the simple rule of thumb to pretension a track line with one hauler using a 3:1 mechanical advantage. This rule would allow a safe amount of pre-tension in the track line so that when the load reached mid-span, the resulting vector force would not generate forces that would compromise any components in the system.

Going into this test I referenced work done by Walker, DJ and McCullar II, Russell. 2014, Slow Pull Testing of Progress Capture Devices and Mauthner, Kirk. 2014, Moving Beyond the 10:1 SSSF. It was my hope to apply some of the results and concepts of these two excellent papers to a backyard quick look at track line pre-tensioning in a high line system.

We conducted a backyard slow pull test with a single-track high line and a double-track high line with a 100-foot span. To make the test easy, we set these high lines up on flat ground between two trees and pulled laterally at the mid-span point while measuring pull force at mid-span and at the tension side main anchor with load cells.

I wanted to know what forces we would see at the anchor and how much the track line would deflect with specific mid span load with increasing amounts of pretension. I particularly wanted to observe if and when a progress capture component reached its system operation limit and slipped, thereby relieving tension on the system.

To conduct the test we used:

- 4-year-old 12.5mm CMC Static Pro Lifeline with approximately 10 days use per year
- Two recently calibrated CMC Rescue Enforcers
- One 10k lb. S beam load cell with a Chatillion DFS force gauge.
- CMC sewn 8mm prusiks
- Two CMC MPDs

We made an attempt to run three synchronized cameras showing the anchor load cell, the mid-span load cell and an overhead camera showing deflection. We were not able to reliably show the mid-span load cell real-time on camera due to Bluetooth range issues with our hardware. All load cell measurements were backed up with a manual read at 200, 400, 600 and 800 pound loads.

Pretension was generated with one hauler except test 6 where two haulers were used.

The load was generated with a 10:1 compound pulley system.

The following chart shows the amount of starting pre-tension on the track line in each test and the force at the anchor with corresponding deflection of the track line.

Test 3, 4, and 5 were double or tandem track lines.

Track Line Pull Test Chart. Sept 23, 2017

Test #	Track line	Pre-tension	force @ anchor w/ 200 lb. load	force @ anchor w/ 400 lb. load	force @ anchor w/ 600 lb. load	force @ anchor w/ 800 lb. load	force @ anchor w/ 1050 lb.
1	Single MPD	100	645	1020	1330	na	na
	Deflection	0'	5'	7.5'	9'	na	na
2	Single MPD	290	772	1186	1438	1662	na
	Deflection	0'	4'	6.6'	8.5	10.5'	na
3	Double MPD	116/103	368/320	580/522	776/720	910/886	na
	Deflection	0'	5'	7'	8'	9'	na
4	Double MPD	330/324	528/495	784/740	958/920	1124/1100	na
	Deflection	0'	3'	4.5'	6'	7'	na
5	Double Prusiks	210/227	420/497	698/755	876/927	1050/1110	na
	Deflection	0'	3'	5'	6'	7'	na
6	Single MPD	516*	944	1276	1526	1746	1954
	Deflection	0	3.5	6	8'	10	12.5

* Two haullers pulling as hard as they could on a 3:1

Observations:

1. Once the track line or lines were pre-tensioned, the rope slowly continues to stretch at a rate that we were not able to measure. If the track line is loaded immediately, the force measured at the anchors seemed consistent between tests.

2. Rope has elastic quality (the ability of it to return to its original length or shape). After each test the rope was obviously stretched and took some time to return to original length. We did not time that recovery or measure each rope between tests.

3. We placed tape on the rope near the MPD swing brake to observe any slippage but we never observed any slip. We set test 6 up to hopefully produce slip by placing five times normal pre-tension on the track line and then putting 1050 lb. of force mid-span. This far exceeded normal operations but remained below the system operation limit of the MPD.

4. We primarily tested the MPD as a progress capture and force-limiting device in single and tandem track lines but we did one test of the traditional equalizing tension system for tandem track lines using tandem prusiks. Interestingly, the side-by-side MPDs seemed to provide as good as (if not better) equality in track line tension.

5. Rope weight itself generates force and this horizontal test does not include rope weight.

Conclusions and recommendations

When applying the concept of force limiting to high line systems, this quick test seemed to show that it would be very difficult to reach the system operation limit (point of slip) on an MPD when using 12.5mm rescue rope. We applied severe pre-tension and a 1050 lb. load and ran out of travel in the mechanical advantage used to generate our load. I think we were close to the system operation limit of the MPD but we did not see slip.

We did not test the Petzl I'D but based on data presented by Walker and McCullar, I think it would have slipped on some of these tests which would be a good thing although their research indicated that the I'D has a greater tendency to strip the sheath on older rope in the 1400-1800 lb. range.

I do not think that tandem prusiks would ever function as an effective force limiting mechanism as it would be extremely difficult to generate the force needed (about 5000 lb.) to cause the prusiks to slip. Extensive published testing also shows that in most cases, tandem prusiks only slip a short distance before either de-sheathing the rope or breaking at the prusik hitch.

We tend to overbuild everything and I would say that the conventional rule of thumb of pre-tensioning a single track line with one hauler using a 3:1 with an MPD progress capture is very conservative. Tandem prusiks are traditional and are probably also very conservative with 80-100 lb. pretension.

Tandem track lines pre-tensioned with either MPDs or I'Ds as progress capture and force-limiting elements are efficient, simple and a very safe way to get the job done.

If one applies the 10:1 SSSF rule, 900 lb. would be the target force on the system. Keeping below 900 lb. with a two person load on a single track line would probably mean no pre-tension and perhaps even some visible sag in the system (as many traditional texts specify). This, in my opinion, is overkill.

Probably the greater unknown and concern would be the strength of natural anchors in the field. Using best practice with anchor selection and construction should be paramount in constructing a high line system.

Also, critically analyzing the system for potential abrasion to the track line from any sharp edge when deflection occurs. Contact with sharp edges by a highly tensioned rope would obviously be catastrophic.

Recommendations for future research

More testing is always good. I would be interested to see more testing on 200' and 300' spans as well as applying either pretention, post tension or increasing load force to the point that the progress capture reaches system operations limit and slips.

If you could get an unlimited amount of rope, conducting these tests with a fresh rope each time would probably yield more consistent results.