Strength and Failure Mode of the Voodoo Tensioning System

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Abstract:

The Voodoo tensioning system is useful in both sport and rescue contexts; however how these systems operate under extreme loads is poorly understood. To observe the breaking strength and failure modes of the Voodoo, twenty-five systems were built from three different static rope types, and slow pulled to failure. All samples failed at a knot, so the Voodoo has the strength of the knotted rope, depending on the rope used and knots employed. Under load none of the systems slipped, so the internal friction of the rope on carabiners holds the system in place even to the point of rope failure.

Introduction:

Tensioned lines are often useful in sport and rescue contexts: For example, when making pre-tensioned backties, in rapid tensioning for river rescues, or building a tensioned traverse with minimal equipment while canyoning. One method that has recently received substantial attention is the Voodoo tensioning system (Figure 1). It is a simple tensioning system that can be built rapidly with minimal equipment in numerous configurations (Evans 2015). While it has many uses in both sport and rescue, the strength of these systems has never been tested, and ultimately it is unknown how they function in practice.

The work presented here is a first step in understanding the properties and behavior of the Voodoo tensioning system as a means of constraining when and where it can be utilized safely in practice by investigating how strong the system is and how it fails when loaded. To answer these questions, twenty-five Voodoo systems were built out of three static rope types and pulled to failure, noting breaking strength, location of failure, and behavior under load (e.g., presence of rope slip).

Figure 1: The Voodoo tensioning system constructed with a clove hitch and a slip barrel knot (Poacher's Knot in Ashley Book of Knots #409, p. 65). Many other configurations are possible (see Evans 2015 for more examples).

Materials and Methods:

New, unused rope was donated by Pigeon Mountain Industries (PMI), the details of which are found in Table 1. The rope was cut into 3.96 m (13 ft) lengths, then built into Voodoo's on a materials testing apparatus. They were built using three ½ inch hardware store screw links, with a butterfly knot at one end and a figure 8 on a bight on the other end. The rope end was secured with a 4 wrap high strength tie off around a 4 inch diameter bollard (Figure 2).

Samples were then pulled to failure with a hydraulic ram moving at a rate of 8 inches per minute and recording the forces they experienced with an Omega LCCA-15K load cell making 200 measurements a second. After a Voodoo broke, the location of failure was identified and recorded. Descriptive statistics were calculated in Excel.

Table 1: Rope types, diameters, and construction for the ropes used

Rope Type	Diameter (mm)	Sheath/Core Composition
Isostatic	11.5	Polyester/Polyester
Classic Pro EZ (EZ Bend)	11	Nylon/Nylon
Classic Sport Max (Pit Rope to cavers)	11	Nylon/Nylon

Figure 2: The Voodoo tensioning system built with a high strength tie off, butterfly, figure 8 on a bight, 11 mm PMI EZ Bend, and ½ inch hardware store screw links.

Results:

Table 2 reports the breaking strengths (in kN and lbs), failure locations, and descriptive statistics for all samples from all three rope types. Table 1a reports results from the Classic Sport Max rope (N=10) with an average strength of 25.4 kN (5700 lbs), a standard deviation of 1.3 kN (295 lbs), maximum of 27.3 kN (6129 lbs), minimum of 23.1 kN (5195 lbs), and a range of 4.2 kN (934 lbs). Table 1b reports results from the Isostatic rope (N=11) with an average strength of 19.6 kN (4413 lbs), a standard deviation of 1.1 kN (237 lbs), maximum of 21.6 kN (4845 lbs), minimum of 17.4 kN (3907 lbs), and a range of 4.2 kN (938 lbs). Table 1c reports results from the Classic Pro EZ rope (N=4) with an average strength of 23.8 kN (5347 lbs), a standard deviation of 1.3 kN (297 lbs), maximum of 25.2 kN (5672 lbs), minimum of 22.3 kN (5012 lbs), and a range of 2.9 kN (660 lbs). Please note: The descriptive statistics for the Classic Pro EZ samples are based on only a sample size of four, so they are unlikely to capture the majority of the behavioral variability in this rope type.

Figure 3 is a box and whisker plot of the descriptive statistics for each data set. These graphs are a rapid (at-a-glance) way of comparing descriptive statistics between data sets, and the plot shows that the strength of the Voodoo systems are a function of the rope from which they are built, though within each rope type the behaviors are consistent.

All samples broke where the rope entered the butterfly knot on the side of the knot closest to the high strength tie off (Figure 2). In addition, while the Voodoos were being pulled, none of the ropes slipped over the screw links, but stayed in place as the ropes stretched.

Discussion and Conclusions:

As a community of sport and rescue rope users we have decided that rope strength reduction from some knots (e.g., figure 8's, bowlines, etc.) is an acceptable loss of strength during use. The Voodoo appears to have the strength of the knotted rope, depending on the rope type used, and the knot tied. This means the Voodoo is as strong as any other sport or

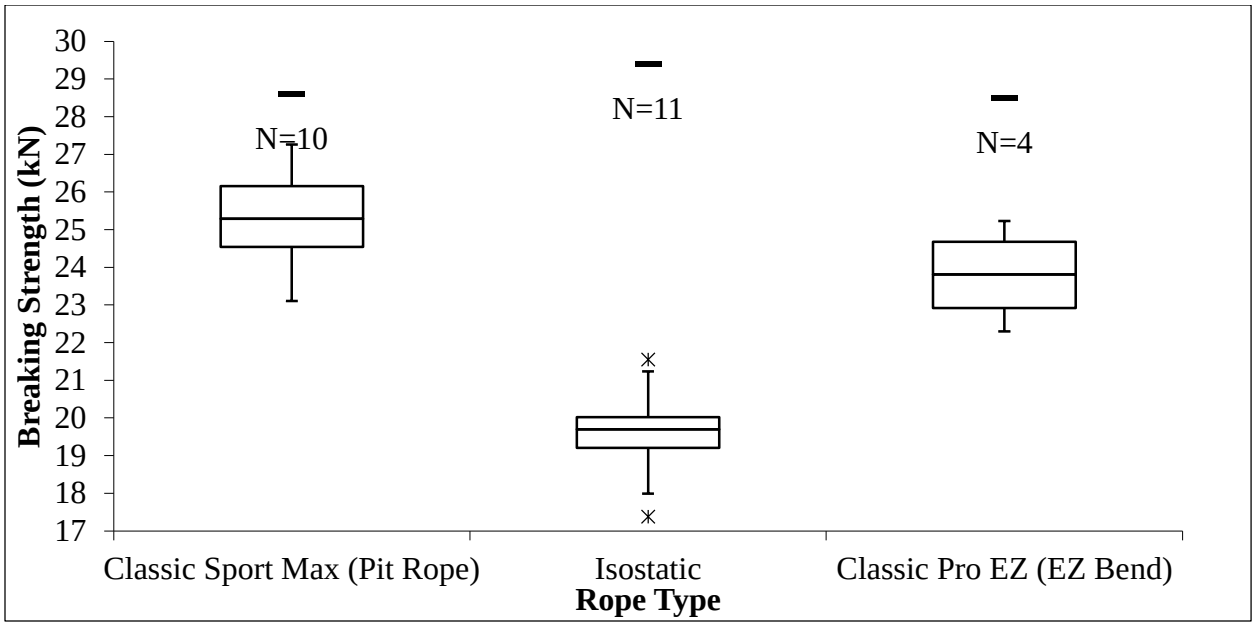

Figure 3: A box and whisker plot depicting the data set averages (horizontal lines), 3/4^{ths} and 1/4th quartiles (box upper and lower bounds respectively), ranges (vertical lines), outliers (*), and manufacturers rated breaking strength (-).

rescue rope system, and can be safely used for these functions. It should be noted that the forces measured in the system are higher than the rated strength of some carabiners, so it is possible, that the weak point in the Voodoo is a carabiner rather than a knot, depending on what hardware is used for construction.

It is notable that during a pull, the Voodoo's did not slip. The internal friction within the system is strong enough to hold the Voodoo in position when fully loaded even to the point of rope failure. This means the failure mode is not through the system slipping and relieving tension, but through material failure, contrary to the suggestions of some users.

Next Steps: It is possible that similarly built systems may behave in a similar manner. For example, the Poldo tensioning system is similar in construction to the Voodoo (Evans 2015), so it is possible that the internal friction within the Poldo will also be sufficiently strong to hold in place while loaded. However, it is likely that the Poldo will break at a higher strength than a Voodoo because Poldos hold the load with two strands of rope at all times (unlike Voodoos), so it is unclear what the weak point is in those systems. Further testing is warranted to answer this question.

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Literature Cited:

Evans, Thomas, 2015, The Voodoo and Poldo: Simple Tensioning Systems, Posted on the SAR^3 "Technique Descriptions" page (http://sarrr.weebly.com/technique-descriptions.html).

Table 1a: Results from the Classic Sport Max (Pit) rope.

Sample #	Breaking Strength (lbs)	Breaking Strength (kN)	Failure Location
V1	6129	27.3	All samples failed where the rope entered the butterfly knot
V2	6099	27.1	
V3	5591	24.9	
V4	5433	24.2	
V5	5915	26.3	
V6	5777	25.7	
V7	5195	23.1	
V8	5630	25.0	
V9	5493	24.4	
V10	5739	25.5	
Average	5700	25.4	
Std. Dev.	295	1.3	
Maximum	6129	27.3	
Minimum	5195	23.1	
Range	934	4.2	

Table 1b: Results from the Isostatic rope.

Sample #	Breaking Strength (lbs)	Breaking Strength (kN)	Failure Location
V11	4490	20.0	All samples failed where the rope entered the butterfly knot
V12	4461	19.8	
V13	4428	19.7	
V14	4638	20.6	
V15	3907	17.4	
V16	4512	20.1	
V17	4319	19.2	
V18	4318	19.2	
V19	4387	19.5	
V20	4845	21.6	
V21	4240	18.9	
Average	4413	19.6	
Std. Dev.	237	1.1	
Maximum	4845	21.6	
Minimum	3907	17.4	
Range	938	4.2	

Table 1c: Results from the Classic Pro EZ (EZ Bend) rope.

Sample #	Breaking Strength (lbs)	Breaking Strength (kN)	Failure Location
V22	5012	22.3	All samples failed where the rope entered the butterfly knot
V23	5507	24.5	
V24	5198	23.1	
V25	5672	25.2	
Average	5347	23.8	
Std. Dev.	297	1.3	
Maximum	5672	25.2	
Minimum	5012	22.3	
Range	660	2.9	