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HEAD RUSH TECHNOLOGIES WHITE PAPER

zipSTOP Redirection Lines

September 2018

This white paper is meant to identify the unique stresses of a zipSTOP zip line brake redirect rope, educate on rope materials and construction, and pinpoint the most suitable options for use with a zipSTOP zip line brake. Head Rush Technologies manufactures one component of a zip line braking system, and for it to function as designed all integral parts must work together in a complimentary way. These components include (but are not limited to) the zipSTOP brake, zipSTOP mounting system, brake trolley, redirect line, and associated hardware (pulleys, etc.). In order to educate consumers, Head Rush has recently reevaluated zipSTOP Redirect Line Requirements. See the end of this paper for a summary of all the current zipSTOP redirect line specifications.

REDIRECT LINE PROPERTIES

Strength

All the kinetic energy a rider has ($\frac{1}{2}mv^2$) must be transferred to the braking system, and in the case of a zipSTOP a critical link that this energy must flow through is the redirect line. Since a zip rider can carry the same energy into a brake system as they would jumping off a four story building this critical link must be incredibly strong. Head Rush Technologies mandates a minimum breaking strength (MBS) of 4,200lbf or 18.7 kilonewtons (kN). The Gorilla Rope is a high strength rope that meets these standards.

Weather Resistance

Few of us leave our harnesses, lanyards, or safety ropes outside for the course of an entire year. Redirect lines, on the other hand, see continual weathering and harsh conditions season after season. For this reason, inspection is crucial, as is regular replacement, but why not try to maximize the effective life of our redirect lines by choosing a weather resistant rope? Properties such as high UV resistance and water resistance are necessary for the longevity of a redirect line. When a rope is saturated with water, not only do the load absorption characteristics change, but the weight increases greatly leading to the problems discussed in the previous section. A hydrophobic and UV resistant rope like Gorilla Rope is going to provide the longest lasting and highest performing redirect line.

Weight

A rope can easily be made strong by increasing size (and therefore weight), but a heavy redirect line will have negative effects on the braking system. Heavy lines create extra friction, sag more, slow or totally inhibit proper reset, require additional tension and can seldom be pulled tight enough to minimize slack. Extra redirect line in the system can sag into the zip path and create dangerous tangles around the cables or even the incoming zip line participant. Another negative of heavy redirect lines is explained by Newton's 1st Law. Since a heavy redirect line tends to stay at rest more than a light one, harsh and inconsistent braking can occur as the rider overcomes the extra redirect line mass to activate the zipSTOP. This is one of the reasons Head Rush sets the maximum redirect line diameter at 6mm.

Elongation

Zip line braking is all about consistency. In a world of endless variables that we don't always have control over (see our paper on Variables of Terminal Braking for more info on this) the last thing needed is one more question. Dimensionally unstable ropes are enemies to consistent terminal braking. Stretch is the recoverable elongation or elasticity of a rope when loaded. Like a bungee cord that elongates then returns to its initial length once unloaded, all fibers elongate under load to different extents. Redirect lines that stretch lead to inconsistent activation of the zipSTOP resulting in inconsistent braking. Another factor is the permanent or non-recoverable elongation that all fibers have after receiving a load. A great way to explain this is to think of a plastic shopping bag. When held by the handles with too much weight the plastic will "stretch" - the handles get longer and skinnier. While they may not break they never return to their initial length either. A fiber that continually or significantly elongates will need constant adjustment when used in a redirect line. The final contributing factor on elongation is construction based. Just like your zip lines that get longer after the first days, weeks, months, or even years depending on how much they are used, redirect lines will elongate as the braided structures compress together. Certain construction styles will exhibit less construction-based elongation, and some manufacturers will

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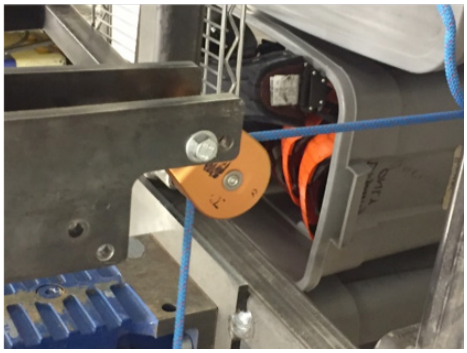
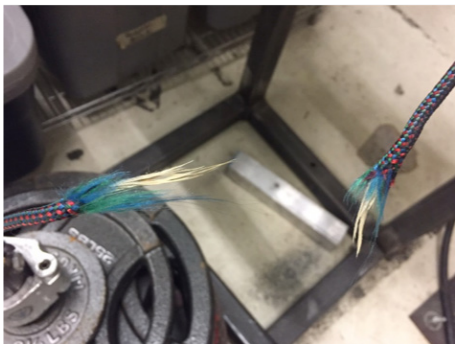
"pre-stretch" a rope to minimize both this and creep once it's in the field. Head Rush recommends a low stretch static rope with a balanced construction and braided core.



Abrasion Resistance

zipSTOP redirect lines are in constant motion while in use, running over and through fittings of various sizes and materials. A high-quality abrasion resistant rope addresses this issue with the design of both the sheath and the core. Having an abrasion resistant sheath will extend the life of the redirect line and is a Head Rush mandate. The other side of this topic is internal to the redirect line. As the core fibers are stressed against each other in knots, point loads, and run over sheaves while under tension they start to abrade each other. Head Rush has done extensive testing to see just how these real-world situations wear different fibers – and the results were shocking. After a cyclic test of 10,000 movements over a sheave at standard zipSTOP operating loads Gorilla Rope showed sheath wear but no overall loss of strength in pull testing. The aramid (Technora) ropes would fail within 2-3,000 cycles with no visible wear to the sample. Each separation occurred directly on the pulley sheave proving the brittleness of aramid fibers when loaded over a small radius. After confirming these results multiple times Head Rush has decided to disallow the use of aramids in zipSTOP redirect systems.



Knotability

For ease of install and adjustment in the field the ability of redirect lines to hold and maintain strength when knotted is crucial. Gorilla rope has a flexible braided core that maintains adequate strength with common knots and a sheath to ensure knots set well and do not slip under load. See manufacturer's recommendations for appropriate terminations in your redirect lines.

INTRODUCTION TO ROPE FIBERS

Nylon

Nylon has a great ability to absorb loads by stretching, which makes it a great choice in certain applications such as climbing ropes but a poor choice for redirect lines. It is UV and abrasion resistant and used in many applications from boating to camping to recreational climbing. The original formula of nylon was invented in 1935 by a DuPont scientist.

Polyester

The first polyester was made in 1941, and 10 years later DuPont released Dacron® as the first commercially available polyester. Initially used in clothing that was cheap to produce and resisted wear and wrinkling, polyester soon became widely seen in everything from ropes to plastic bottles. Polyester is quite abrasion, UV, and water resistant, however it does not achieve the appropriate strength to weight ratio for the demanding needs seen in zip line braking.

Aramids

A family of fibers consisting of well-known names like Kevlar™, Nomex®, and Technora®. Very high melting points and extremely cut resistant, these fibers are easily degraded by UV light and are very brittle when bent around small radii such as a knot or pulley sheave. This propensity to fail without warning at low loads in bending applications makes them a potential danger in a zipSTOP redirect system and cannot be used. Aramids are used in everything from fireproof ropes to bulletproof fabrics and have been in use for over 50 years.

UHMWPE

More commonly known as Spectra® or Dyneema®, both name brands for these fibers produced by different mills (Honeywell and DSM), ultra high molecular weight polyethylene (UHMWPE) fibers have unmatched strength to weight ratios. Stronger than steel yet they float in water (and don't absorb it either). Invented 60 years ago but made widely available in the last 25 years, these fibers can be found on high end sailing rigs, heavy duty winching and lifting operations, and in fishing line. A rope with a braided (balanced) UHMWPE core and abrasion/UV resistant sheath is the appropriate choice for redirect lines.

Material	**UV Resistance**	**Stretch @ Break**	**Abrasion Resistance**	**Density (Specific Gravity)**	**Melting Point** (°C)
Dyneema®	Very High	3.1%	High	0.97	145°C
Technora®	Low	4.6%	Low	1.39	500
Nylon	High	30%	Medium	1.16	245
Polyester	Very High	14.5%	High	1.38	250
*Approximate based on averages seen					

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Redirect Pulleys

Once an appropriate redirect line such as Gorilla Rope has been selected for an install, it is vital to ensure any redirect pulleys used are compatible to prevent premature wear or poor overall braking performance. When a rider engages the brake trolley redirect lines move at speeds equal to that of the incoming rider, therefore having a premium pulley with high quality bearings is important to minimize friction in the system. This extra friction can lead to harsh or inconsistent braking and increased wear. Another important factor is matching the sheave to the rope used. Sheave diameter and profile is important to maximize rope life and eliminate hazards of snagging or jamming re-direct lines in pulley housings. The synergy between Gorilla Rope and the Head Rush Precision Pulley is designed to maximize lifespan of both components, minimize risk, and improve overall braking performance.

Summary

Gorilla rope was originally selected for its compatibility with the zipSTOP zip line brake, and remains the best choice for this application. To maximize braking performance Head Rush now states that Gorilla Rope and Precision Pulleys, or their direct equivalent must be used in all zipSTOP installs. See the latest zipSTOP Manuals here to learn more.

Redirect Line Specs

Diameter	6mm
Static Strength (Minimum)	18.7kN (4,200lbf)
Elongation (Max)	@ 10% of break load: 0.51% @ 20% of break load: 0.89% @ 100% break load: 3.6%
Max Operating Temps	80°C (176°F)
Weight	2.4kg/100m (1.5lbs/100ft)
Material of Core	Dyneema® SK78 (or equivalent)
Material of Sheath	Polyester (or equivalent)