The Line on Hurricanes

Why Do Some Nylon Anchor Lines Hold and Others Break in a Storm? (And Why Is the Anchor Line You've Been Using for Years Likely to Fail?)

As sometimes happens in early spring, a line of dark clouds suddenly appeared on the horizon and Dan Arsenault got caught in an especially violent April thunderstorm. He was bringing his 37' sailboat from its winter storage yard to its summer home near Saginaw Bay, Michigan when the wind built to near-hurricane force (74 knots) and seas grew to nine feet.

Dan's boat was passing through a narrow channel and was bounced off the bottom several times, damaging the rudder. After a brief attempt to work his way into the marina, Dan crawled up to the bow, set the anchor and went below to wait for the wind to subside. Moments later, amid the horrific noise of the storm, he heard a loud "explosion." The anchor line had parted.

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In less trying conditions, nylon's ability to stretch makes it an almost perfect choice for an anchor line. The stretch absorbs shock, which means less strain on the anchor, less jerking, and a more comfortable night's sleep. One of the most frequent complaints from BoatU.S. Hurricane CAT Team members, however, is that the same nylon rodes that are fine for everyday use have proven to be woefully inadequate in a violent storm. In Florida last year, hundreds of boats were driven ashore because their nylon anchor rodes—usually more than one—had parted.

When a boat winds up on the beach after a storm, it's easy to look at the frayed remains of the anchor line and announce that it had chafed. The solution has typically been to recommend more and better chafe protection. The fact is that the "chafed" line could have broken—exploded—under a tremendous load because it lacked strength; it could have failed suddenly because it lacked elasticity; it could have failed internally—melted—by the tremendous heat; or it could have failed for a combination of reasons.

While there are plenty of examples of nylon anchor lines that failed in storms, there have been at least as many examples of anchor lines that survived, despite having been tested for many hours by the same high winds and seas. *Seaworthy* talked to representatives from the major rope manufacturers as well as members of the BoatU.S. Hurricane Catastrophe Team to find out why some anchor lines—and boats—are more likely than others to be counted among a storm's survivors.

Five Critical Factors that Predict How Rope Will Fare in a Storm

1. *Breaking strength* is determined by wrapping new rope around two large-diameter capstans and slowly tensioning the line until it breaks.

All things being equal, a braid-on-braid line will have the most breaking strength followed by plait and then three-strand. You might think that breaking strength (tensile strength) would be the ultimate criterion for selecting an anchor line. After all, the line that's the strongest would have the best chance of surviving the tremendous forces in a hurricane. Alas, the forces on a rope in a hurricane are not applied slowly on large-diameter drums; it takes more than breaking strength for a rope to survive something as violent as a hurricane. Breaking strength is only one of five factors.

2. *Stretch*. While breaking strength is clearly important, stretch is also essential to act as a shock absorber for the tremendous amounts of energy. There are two ways that a rope absorbs energy: 1. The material itself stretches, and 2. The weave of the material can expand and contract mechanically. Before the fiber itself stretches, the lay of the rope untwists and absorbs energy.

Nylon stretches more than polyester and, all things being equal, a three-strand twist line will stretch more (and absorb more energy) than a braid-on-braid line. A plaited line (similar to three-strand but softer and with a square profile) will stretch more than either three-strand or braid-on-braid.

Without something that stretches to act as a shock absorber, the intense gusts and surging waves are much more likely to yank an anchor out of the bottom. A line that stretches also helps to prevent a boat from "sailing" back and forth, which puts additional strain on the anchor and rode. The greater its ability to absorb the sudden and violent stresses, the less likely an anchor line will fail.

3. *Chafe and Cleat Location*. All of this stretching back and forth across a chock has the potential to chafe the line, especially if it is secured to a cleat that is a foot or two away from the chock; the increased distance gives it more room to be stretched. If the chock isn't well rounded and smooth, all of this rubbing under pressure will quickly lead to external chafe. Note, however, that the potential for external chafe is only one of several ways a line can fail at a chock. When the line is bent sharply down to the water, only about *half* the rope's fibers are taking the load. Because of compression, the remainder of the fibers will be ineffective.

Stretching and rubbing at a sharp angle also

Continued on page 12

HURRICANES, *from page 11*

create heat, a lot of heat. Nylon line starts to deteriorate at 300° F, and at 350° it will have lost *half* its strength. There have been many instances at a chock where lines have melted and failed *internally*.

4. *Age*. The nylon fibers that are woven together to make a rope are thinner than a human hair. One thing you don't want in contact with a nylon rode is dirt, which, over time, abrades fibers and weakens the line. Salt crystals, while not as destructive as dirt, also abrade fibers.

Unfortunately, dirt and salt are found in abundance on the sea bottom, which means that an older line, even one that is healthy-looking and supple, may be significantly weaker than its spanking-new counterpart. Fibers are also weakened by sunlight and exposure to certain chemicals, including acids and alkalis.

There are other ways that nylon rope can be affected by age. Repeatedly expanding and contracting weakens the fibers; the more times the line has been used and *heavily* stressed, the more likely it has been weakened. Again, damage and loss of strength may have occurred without any discernable signs of weakness.

Some types of damage are apparent. As they get older, nylon lines become stiff as they shrink and fibers lose lubricant. Better-quality nylon line is pre-shrunk but it's not possible to eliminate all shrinkage; some is inevitable. The lubricant, also found on better nylon line, minimizes shrinkage by keeping water from penetrating the fibers. Lubricant has the considerable added benefit of reducing yarn-on-yarn friction, which helps to reduce heat. As noted earlier, excessive heat can severely weaken nylon line.

Two obvious indications that the line is shot are stiffness and, when it's under load, "squeaking." But what about a well-used nylon line that is still supple and looks healthy? With industrial applications, rope is often retired at predetermined intervals, typically after two - three years of everyday use, to prevent catastrophic failures. Nobody knows how long an anchor line should be depended on, but a line that has been used hard and often will likely be significantly weaker than a new line.

5. *Line quality*. As noted, better-quality line is pre-shrunk with lubricant added to the fibers. The way a line is woven is also important. Three-strand twist should always be built with a medium lay construction. The latter has more twist ("mechanical twist") and will absorb energy more readily than rope made with soft-lay construction. While easier and cheaper to manufacture, soft-lay rope is much more prone to failure. If it's easy to separate the strands, the line is probably soft-lay. Braid-on-braid rope can also be made with a soft-lay construction, but it "herniates" readily and is far less common.

First, consider that if the chock isn't smooth and well rounded, the line will quickly be chafed through as it moves back and forth in a storm. Consider also that when a line is being compressed at the chock under storm loads, it can lose half of its strength. Finally, consider that all of the stretching back and forth under tremendous pressure in a storm can generate enough heat at the chock to melt the nylon fibers. Question for boatbuilders: Doesn't it make sense to eliminate the chock altogether by locating the cleat directly on the rail?

Some Possible Solutions to the Problem of Failed Rodes

The question for boat owners is what type of line or lines will stand the best chance of surviving a hurricane?

First, the obvious: The boat's chances of surviving a storm can be improved significantly by using more and larger lines. All things being equal, a 3/4" line will outlast a 1/2" line and two 3/4" lines will outlast a single 3/4" line. The size of the lines will likely be determined by the size of the cleats.

Another obvious choice: A rode (and storm anchor) that is used purely for anchoring the boat in a storm should be made up before the start of hurricane season. The boat's everyday working rode should not be relied on; it probably isn't big enough and, if it has been in use routinely, much of its resiliency and breaking strength may have been compromised.

A Rode Is a Rode Is a Rode . . . *Anchoring Outside the Box*

Using larger and healthier lines is a good start, but there are more choices yet to be made. For starters, what type of line—braid-on-braid, three-strand, or plait—will work best? After Dan Arsenault's harrowing experience (the boat survived, albeit with a bent rudder shaft and two badly shaken crew), he replaced his failed nylon braid-on-braid rode with nylon three-strand. The reason, he said, was that the three-strand line has greater elasticity—more stretch—to absorb the violent loads. The bow of his boat had been thrown high into the air by waves in the open water and the lack of elasticity in his line (and perhaps its age) led to the failure. Would three-strand or plait have survived? It's hard to say.

The obvious question is how much of a trade-off in breaking strength do you want to make for additional energy absorption? Once again, the answer is that nobody knows. It could be (with no studies to back it up) that using three-strand nylon or plait to maximize energy absorption is more critical in an exposed anchorage where the bow will be thrown high into the air by large waves. Loads are applied suddenly and violently and the line will have to absorb a tremendous amount of energy if it has any chance of surviving. In a sheltered harbor, waves (and sudden shock loads) should be significantly reduced. Wind would then become the primary force acting on the boat, and opting for increased breaking strength (braid-on-braid or even polyester) might be a better choice.

A few words about polyester are in order.

Continued on page 13

One of the rope manufacturer's experts, who also happens to own a boat, said he would consider using a combination three-strand polyester rode with a nylon rode in a hurricane. The two could be looped eye-to-eye to avoid having a knot in the line. (Knots weaken a line by as much as 50%.) Polyester would be used from the cleat through the chock, where the rode is most likely to be stressed, with the remainder of the rode being nylon.

Comparable Average Breaking Strengths For Different Rope Sizes and Types*

	Braid-on-Braid	Three Strand	Plait
1/2"	8,300	6,100	6,300
5/8"	17,000	9,350	10,400
3/4"	21,000	N/A	16,200

* Source: Yale Cordage

It's an interesting idea that was first introduced by Norman Doelling (*Seaworthy* April 1995), who was then the assistant director of the MIT Sea Grant Program. Polyester is much tougher and far more resistant to chafe, both internal and external. Nylon is more comfortable in the under-25% range of its breaking strength, but beyond that it begins to quickly fatigue. Polyester has the capability of going to 50% – 60% of its breaking strength without fatiguing, at least not quickly. Even when wet, polyester line retains full strength (nylon loses strength, although water is necessary to cool the stressed fibers).

There are other alternatives to conventional nylon anchor lines. Yale Cordage makes a braid-on-braid mooring pennant that has a nylon core for stretch and shock absorption and a polyester outer core to resist chafe. The outer core is woven to produce stretch (mechanical) that is comparable to stretch in the nylon core. The line is sold in shorter lengths with eyes for use as mooring pennants. Yale sells the line in spools for other markets, but it can be special-ordered by a marine chandler.

Another choice mentioned frequently by manufacturers' experts is plait. The main selling points of plait have been that it is soft and pliable, takes up less space in an anchor locker than other rope types, and can be twisted without hockling. But plaited rope is also more elastic and has more breaking strength than three-strand (although it is not as strong as braid-on-braid). It is also worth noting that plait is easily spliced.

Chafe Protection

Cleat location is a significant weak spot that is often overlooked when a boat is prepared for a hurricane. A cleat that is located on the rail is ideal because it avoids heat buildup, loss of strength, and chafe caused by stretching rope across the chock at a sharp angle down to the water. The line won't be compressed as tightly, it won't generate as much heat, and it will be far more likely to weather the storm intact.

On boats where the cleat is located back from a chock, it may be possible to move the cleat. Note, however, that the cleat must be installed properly or the whole effort will have been for naught. Bolts and not screws should be used to secure the cleat, and it should be backed with a wood or metal backing plate to distribute the load (washers are not adequate).

If the cleat can't be moved, the choice of chafe protection will be critical. Various types of hoses—PVC, garden hose and even fire hose—have the potential to reduce compression at the chock as well as protect the line against external chafe, which is good. But these types of hose will allow heat to build up and prevent cooling water from reaching the fibers. The best way to reduce the chances of the line failing at the chock is to use something like polyester chafe protectors, which let heat out and allow water in.

Don't forget that rodes can be chafed underwater as well. Chain should be used between the anchor and anchor line to prevent chafe on the sea bottom. If a lot of chain is used, at least a third of the rode should be nylon line to absorb shock. Make sure the thimble splice is snug; loose or broken thimbles have been the downfall of more than one anchor line in a storm.