How-To

Get High-Tech with Line

By Jack and Alex Wilken

The boat show is around the corner, and winter is upon us, but we are experiencing some pretty nice weather. Looking out onto the lake, there is a nice breeze and plenty of sunshine. With sailing in mind - sorry if that sounds like a broken record, but we seem to have sailitis - we want to share with you a subject that has kind of 'creeped up' on all of us (that pun will make sense in a few paragraphs!).

There has been a steady march forward in rope technology since the 1940s. The true beginnings of rope making are lost in prehistory with fossil evidence from as early as 17,000 BC. Until the 1940s there were only natural fiber and metal ropes available. Since the 1970s, the speed of the rope revolution has accelerated exponentially. One of these discoveries is High Modulus Poly Ethylene (HMPE), which starts out as something not much different than the material of a reusable shopping bag. We are going to focus on the use of these fibers for running rigging, and, though we will not get into it in this article, they are also used for lifelines (February 2013 *48° North*) and even standing rigging.

HMPE, also known by other acronyms, has come to play a major role in yachting. HMPE's low stretch yields better control, especially for sheets, guys, and halyards etc. on race boats, though their application in the cruising realm continues to expand. Jib sheets and halyards will keep the sail flat instead of letting it become fuller with gusts and puffs, and main sheets will maintain their control of the leach better. HMPE spinnaker sheets or guys will not absorb or hold water, and, therefore, will stay light so they do not pull the spinnaker clews down in light air. One thought here is that stretch will absorb some of the driving force of the wind, so reducing it, as HMPE does, captures more force to move the boat. How much you get from any one or the combined effect of these is hard to say, but there is no denying the physics.

Cruising and racing boats will both enjoy the benefit from HMPE sheets and control lines that run through blocks and fairleads without jamming. These ropes are made from a combination of different fibers and special construction that facilitate their running free. HMPE is high strength so cruisers will have the advantage of being able to reduce the diameter of some of their lines. Halyards that stretch less are a plus on any sailboat, but, depending on the application, what needs to be dealt with is the creep that HMPE exhibits. Creep is elongation that doesn't rebound and eventually could cause the line to rupture. This sounds bad, but it can be worked with so that problems can be avoided.

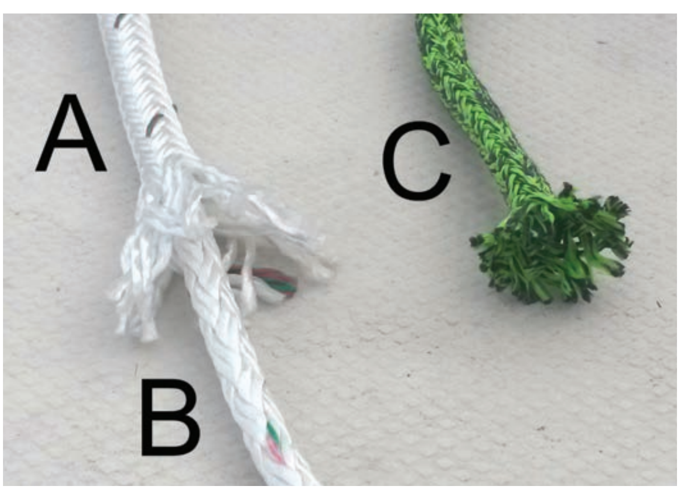

Figure 1: "A" is double braid polyester, and "B" is the core that is being extracted so the cover can be pulled over and sewn onto a Dyneema 12 strand single-braided rope. "C" is a cover that is sold for the same purpose that usually costs more than twice the double braid. As you pull the core out of the "A", you can pull the Dyneema in.

HMPE fibers have a strength-to-weight ratio of 8 to 15 times higher than steel. They have less stretch than 7x19 stainless steel (SS) wire. It seems the only downside for these fibers is creep, and even that can pretty much be designed out, or, just figured in as the product life in those few situations where it even applies. HMPE has good resistance to UV, floats, does not absorb water, and has excellent abrasion resistance.

HMPE's fiber for ropes are marketed under two different names: Dyneema® from the Dutch company DMS, or Spectra® from Honeywell. The two have similar characteristics, but are not the same. They start life as polyethylene, but the chemicals that are used to process them differ. There are also different generations of these products, and, then, there are also differences in individual rope manufacturers' products. When choosing them to replace other rope, you have to pay attention to the specs because you want to replace strength for strength, not size for size. This field is in a constant state of advancement. For instance, watch for new products in the future that incorporate the next generation of Dyneema DM-20 ultra-low creep.

Let us start with halyards. In the last 50 years there has been a slow evolution of the halyard. All wire rope halyards were replaced by wire rope spliced into a rope tail, and then the stainless steel wire began to disappear altogether. The use of flexible 7x19 SS wire rope kept stretch at a minimum, but wire spool winches could be cumbersome and slow, especially for smaller boats. By using a rope tail spliced onto the wire, the stretch was also kept to a minimum. We still had two situations: wire halyards flying around aloft making nasty marks on masts or spreaders, and then there is when the meat hooks start to appear. These broken wires sticking out of a halyard were kind of the last straw. As we come forward from the past, we have low stretch rope halyards, polyester/polyester double braid, which became popular on cruising boats. Fast forward to today and we have HMPE. These fibers mean really

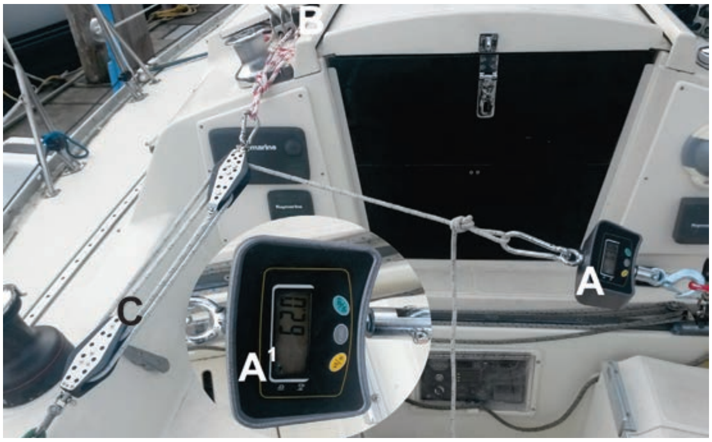

Fig. 2: A load cell or hanging scale can be used to measure how much tension there is on a given line. In this case, we are measuring a furling jib halyard. The scale "A" is in the line that pulls on the tackle "C." The reason to use a tackle in the system is only to bring the tension into the range of the scale you are using. If the tension is 600 lbs. and you are using a 500 lb. scale, by using 2:1 tackle, the pull would be 300 lbs. In this case we used a 4:1 tackle, and the scale ("A¹" is an enlargement of the scale's face) shows 62 lbs. This times 4 gives us the tension of 248 lbs. This was the tension when the rope clutch "B" released. You could also arrive at an approximate value for the tension by doing the math using the winch power ratio, winch drum size, handle length, and the amount of force you figure you put on the handle.

low stretch, even less than SS wire.

HMPE has a low coefficient of friction, meaning it is very slippery. It is often used with an HMPE core and a cover of some other fiber. Halyards will have to be spliced to the shackle, and that splice and the bitter end will need to be sewn - no knots. Also, for gripping on a winch or rope clutch, it is necessary to install or have a cover. This can be done in different ways. Samson Warpspeed II, for example, is high strength, low stretch rope with a Dyneema core and polyester cover.

The halyard can be made with the shackle spliced into the core and the rest of the cover left in place, or the cover can be stripped off in some places, when desired, for greater weight savings. The exposed core also simplifies the splicing process for Dyneema cored ropes. Again, it is important that both the splice and the cover are sewn properly, so the splice will not slip, and the cover sewn to the core wherever it begins and ends, so it will not slip on the core. Cover material, to add to a Dyneema 12 strand single-braided rope, is available as a cover-only product or you can strip the cover off a polyester double braid and use it (Figure 1). The easy, but most expensive choice, is to buy HMPE rope with the cover already installed. The reason to remove the cover, or, only adding it in places where you need it, is to save weight aloft. The actual weight savings may be small, but the idea is that every little bit helps.

When replacing wire halyards with fiber, it is important to inspect your mast sheaves and masthead for sharp edges. The sheaves may need to be replaced if they could abrade the fibers. Make sure your sheaves are turning freely and, in a case where you can, replace your old sheaves with larger diameter ones as it will reduce the bending load.

Sheets, guys, and control lines made with HMPE can be made as a single braid with the HMPE and the polyester woven together. This makes it easy to splice, but also gives it a superior ability to run through blocks without jamming. When tacking, this means there will not be the normal jamming of the sheet you have just released in the turning blocks. (This rope will not solve the problem of someone sitting on what is now the lazy sheet!) This single braid works well for mainsheet control lines; they run freely without a snag through several sheaves lying stacked on top of each other. Samson Control-DPX™ is such a product; it does tend to flatten a little more than its Yale Cordage Ph.D (Performance handling. Delivered) counterpart which uses Spectra. They both zip through blocks and fairleads, and, at the same time, feel good in your hands and grip well in rope clutches and on winches. The DPX is not recommended for self-tailing winches.

Tapering sheets and halyards is another possibility. Halyards are

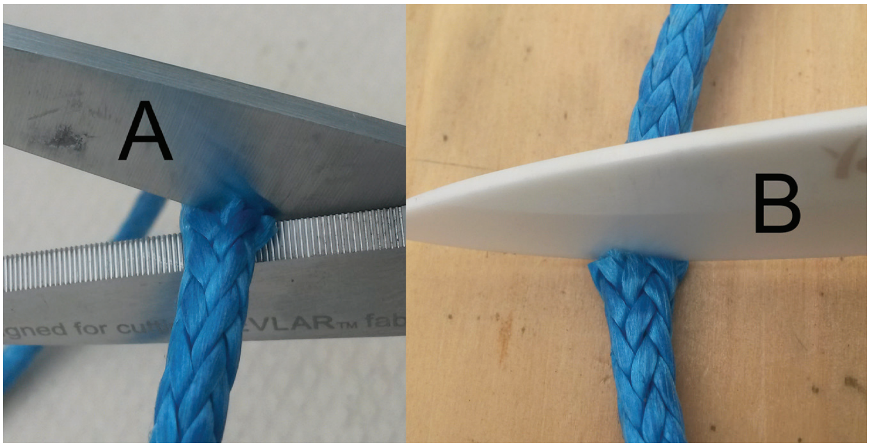

Fig. 3: "A" is a pair of scissors designed to cut Kevlar, but they work well on HMPE. "B" shows a ceramic knife that also holds an edge while cutting through HMPE fiber.

tapered to save weight aloft, just like the cover is removed from the core for the same reason. With sheets, especially for spinnakers, keeping them as weightless as possible in light airs is important. You can take on this marlinspike seamanship task, tapering sheets (http://www.sonar.org/site/files/Library/Articles/How_to.../Tapered_Spin_Sheets.pdf), or go to a local rigger or rigging service. Some of the rope manufacturers offer this service, especially for big boats. Marlow, using Dyneema, is probably at the forefront on this. The reverse of tapering is also done; that is when you add to the core. You add to the core where you need more diameter for rope clutches, handling, etc.

Creep is a factor of the percentage of the breaking strength load. 10% elongation of the line signals end of service life. One way to reduce creep is to increase the diameter of the line. Another is not to leave the line under load when it does not need to be, such as letting the tension off on the furling jib halyards when the boat is at the dock. Temperature is also a factor in HMPE fiber failure, but not until it goes above 110° F. In failure from creep, the thing that we have the most control over is the percentage of MBS (minimum breaking strength). As you increase diameter and therefore the MBS, the same load represents a smaller percentage so you reduce the creep. This requires that you determine the load and choose a rope diameter that keeps you below 30% of MBS. All Dyneema or Spectra rope is not the same and, by changing from one generation to another, we can also change the amount of creep. In an example given by Samson about creep, they calculated that in a given situation (a mainsail halyard on a 60' boat), and assuming 20% of the rated breaking strength of dyneema SK75, that there would be more or less 0.1% creep per month. The line would need to be retired in about 8 years. If you switched to SK78, the creep would be reduced to 0.033% per month, giving a life expectancy of 24 years. All of this assumed that the halyard was under continuous tension, and does not account for any other wear. (Dyneema actually gets stronger in the initial stages of its creep.)

Sizing of the line can be done by looking at the size of blocks you are using. Check the manufacturer's data to see what the rating is on the blocks you are using. Assuming the existing blocks are functioning, you could safely choose a rope based on their breaking load. You may be surprised just how small the loads are. We also have a method for determining the load: use a 500 lb. fish scale, which can be had for $30. By using a tackle to tension the line as you increase the number of parts, 2:1 or 4:1, etc., it will allow you to bring the tension into the range of the scale (Figure 2).

When sewing Dyneema, you can use the strands from another piece as thread. Select a length of Dyneema that is long enough and has strands of the size you want to use for thread and pull out of the individual strands and thread them into the needle. Cutting HMPE fibers will dull a good knife. Ceramic knives have become popular and they will hold their edge, as will scissors especially made to cut this or Kevlar material (Figure 3). HMPE, like Kevlar, is used to make bullet proof vests.

There are many other high performance fibers being used in rope today. This article could not even begin to cover all of them. In (Figure 4) we have given you some comparisons of different types of fibers as they are often mixed with HMPE. Dyneema and Spectra are not the silver bullet in modern rope, but for now they are certainly part of it.

-48°N

FIBER NAME	STRENGTH 7/16" Diameter	UV	CREEP	TEMPERATURE DEGRADATION	FLEX FATIGUE
DYNEEMA SK-75	21,500 lb	+	-	290°-360°F	+
DYNEEMA SK-78	23,000 lb	+	+	290°-360°F	+
SPECTRA 1000	18,000 lb	+	-	290°-360°F	+
VECTRAN	21,500 lb	-	++	536°-660°F	-
TECHNORA	15,300 lb	-	++	1200°F	-
ZYLON	24,000 lb	-	+++	1200°F	-
POLYESTER	5,800 lb	+	-	300°-480°F	+
NYLON	4,800 lb	+	-	419°-437°F	+

Fig. 4: This chart gives some comparisons between different fibers that are used today to make yachting ropes. We mentioned Kevlar, which is not used anymore in sailboat rope because of its failure from fatigue; it is, however, in the family of "aramids", some of which are used, for example, Technora®. These fibers are sometimes mixed and woven into the same rope. This chart is meant as a guide only as the information given is relative.

Jack and Alex Wilken are experienced boat builders and have cruised extensively. They each hold a 100-ton USCG Captain's License and are the owners of Seattle Boat Works LLC in Seattle.