

Dyneema®/ Spectra® Lifelines
Properties and recommendations for its use
By Evans Starzinger

Dyneema® and Spectra® are different brand names for the same very strong fiber (chemically Ultra-High Molecular Weight Polyethylene - referred to below as HMPE). This fiber has very attractive properties: extremely strong (15 times stronger than steel fiber of the same weight) and low stretch for its weight, resistant to flex fatigue (Relative Flexlife: Dyneema® 100, Vectran 55, Aramid 8, stainless steel fiber 6), extreme chafe resistance (8 times lower dry abrasion and 40 times lower wet abrasion than all other conventional fibers) and quite UV resistant. It has been finding increasing usage aboard sailing vessels and has been recently approved as a lifeline material. However it does have some unique characteristics which require special techniques and care for optimal performance.

What type/size of line to use

The Offshore special regulations (ORSs) set minimum allowed diameters for HMPE lifelines. These are 3 mm for under 28-feet LOA, 4 mm for 28 to 43 feet, and 5 mm for over 43 feet. These are the minimum diameter for the load-bearing portion of the line, not to include any covers or sleeves. These minimum diameters have been selected to provide greater strength than the equivalent wire lifelines when the line is new because line is more vulnerable to degradation from UV and to chafe and its strength will decline over time.

Double braid line, sleeves and covers are allowed, so long as the core is pure HMPE and the core alone meets the minimum diameter requirement. So, for example, a 5 mm HMPE double braid line will NOT have a 5 mm core and thus NOT meet the minimum diameter requirement for boats over 43 feet, but may meet the requirement for boats under 43 feet if the core alone is 4 mm in diameter.

There are basically four different line solutions you can use:

1. The minimum allowed lifeline is an HMPE single braid line that meets the minimum diameter requirement for the size boat. As mentioned above and discussed in detail below, this line will degrade over time from UV and from chafe (particularly where it enters and leaves the stanchions).
2. Adding chafe sleeves where the line goes through the stanchions can increase the longevity, durability and safety of this line. This will be discussed in more detail below.
3. Incorporating a cover over the entire line to protect it from UV in addition to chafe further increases the longevity, durability and safety of this line. Some manufacturers have introduced HMPE cover/HMPE-cored double braid line for this use. Some of these double braid covers also have other "value added" features (for example night glow fibers woven in which highlight the deck edge at night).
4. A larger diameter bigger single braid, equal in diameter to the core plus cover/sleeve in solution (2) or (3), will have a much higher initial breaking strength than (2) or (3).

There is some expert debate about whether (4) is preferred to (3). With a HMPE/HMPE double braid line the core is the loaded portion and the cover is only there for protection purposes and does not carry any load. So, if you take two lines of the same total diameter, a single braid where the entire line carries load, and a double braid where only the core carries the load, the single braid will initially be significantly stronger. As a specific example, a specific 5 mm double braid has a breaking strength of 1815 kgs, while a 5 mm single braid (by the same manufacturer with the same HMPE fibers) has a breaking strength of 2691 kgs (almost 50% more). However, in a double braid the core is protected to some degree from chafe and UV while in the single braid

the load bearing fibers are exposed. But the single braid is starting out with almost 50 percent more strength and so can suffer a lot of damage before it drops to the level of the double braid. Based on the UV data discussed below, the single braid will almost certainly be stronger than the double braid for the first two years of use. The test data and empirical evidence is inconclusive as to which is stronger after 2 years of use/UV. With either option, the safest choice is to fit the biggest diameter line that will fit thru your stanchion holes, and then inspect the lines (particularly at each stanchion) at least annually and replace it when you see any significant chafe. Both chafe and UV damage on HMPE line are easily visible as fuzz on the surface.

Splices at the ends

As in all line, splices are preferred to knots where possible. As with all line, a splice in HMPE will be stronger than a knot. Generally a splice will be 90-100 percent of the line strength while a knot in HMPE will be only 40-50 percent of the line strength (excluding the slippage issue discussed below).

For single braids, there are two splices in common usage: the [locked Brummel](#) and the [Bury Splice](#). The single braid Bury is perhaps the simplest of all splices in all types of line. After making it once with instructions, most people can make it again without instructions. This splice must absolutely be stitched with appropriate whipping twine. or the bury may slip when it is unloaded. With stitching it is absolutely secure. The locked Brummel is more complex and many people will require instructions each time they make it. In return for this complexity, the locked Brummel is more secure (but it certainly does not hurt to also stitch even the Brummel splice)) against low load slipping. However, if the buried tail is too short on a locked Brummel, the whole load can come off the 'knot like' locking portion and it will break at much lower than expected load. The buried tail must be at least 63 times the diameter of the line, and some riggers recommend 72x. Both splices are acceptable. The Bury splice is simpler and more resistant to improper construction so should be used by less experienced splicers.

In double braid line you can strip the cover off the ends of the line and use either of the above two splices on the core just as if the core was a single braid line. However, that exposes the core to UV and Chafe at the splices. To avoid this you can either cover the splice carefully with tape, or use a more complex splice (called a [Core to Core splice](#), or [Core to Core 2](#)) which covers the core. These splices are more difficult than the single braid splice, particularly getting the necessary long bury driven home. However do not be tempted to skimp on the bury as it is critical to the strength of the splice in these very slippery fibers.

One most critical factor to proper construction for both splices is a long smooth taper on the buried tail. If the tail is not tapered it will create a stress riser at its end and the splice will fail at that point.

Bend Radius

High modulus lines are weakened if they are taken around tight turns. The entire load comes on the few fibers on the stretched outer edge of the turn and they break and then the line zippers inward. This is why knots dramatically weaken these lines (as discussed below) because the line takes sharp turns inside the knot. With HMPE line, an 8:1 bend radius (the radius of the bend compared to the diameter of the line) is considered gentle enough that no strength is lost, while a 5:1 radius results in a loss of about 15-20 percent of the line strength and is the minimum bend radius recommended. This means that the splices need to go around something (sailmaker thimble, ferrule, low friction ring, pulpit tube, etc) that is (at least) five times the diameter of the line so (about) 1 inch for a 5 mm lifeline. The HMPE lifeline should not be taken directly around the typical small diameter wire bails that are commonly welded on to pulpits. Nor should you take a lashing directly through the lifeline splice (because the lashing will most likely be less than 5 times the diameter of the line). With a lashing, the splice should go around the (proper diameter) thimble and the lashing should pass through the thimble/ferrule/etc.

This is not a perfect execution, but acceptable:



Lashings at the ends

Lashings are usually used at the ends of HMPE lifelines, to provide a light, inexpensive and durable way to tension the lifeline. Cutting them allows the lifeline to be removed quickly when recovering a MOB. The lashing should be as strong as the lifeline itself.

There is a trade-off in the number of turns of the lashing between having enough leverage and friction to tension the lifeline and having too much bulk in the lashing. The optimum is to have between three and six round turns (one round turn gives you two legs of fore/aft line). The photo above shows three round turns (one crosses through the bail to help keep the lashing from slipping up), with three legs on each side of the lashing.

The cord can be Polyester (Dacron®) double braid, or double braid with HMPE core/Polyester (Dacron®) cover or HMPE single braid. Polyester (Dacron®) is inexpensive, suffers small bend radiuses better than HMPE, and holds the knots that terminate the lashing more securely (HMPE is very slippery), while the HMPE is much stronger. Our preference is HMPE core with Dacron cover, but all three will work if sized properly.

To work through a specific example . . . let's say you have 6 mm HMPE single braid lifelines (one size bigger than the OSR minimum for a boat over 43 feet) with a breaking strength of 9,700 lbs and you prefer a lashing with four round turns. That provides eight legs of the cord, so each leg should hold 1,200lbs. Throw in a 30 percent factor for bend radius and knots, so the cord should have a breaking strength of at least $1.3 \times 1,200 \text{ lbs} = 1,500 \text{ lbs}$. As an example, if you like HMPE-cored/Polyester (Dacron®) covered double braid, the 3.8 mm size of New England Rope's Spyderline has an 1,860 lb breaking strength, which is just about what you need.

There are various acceptable ways to install the lashing. One good method is:

1. Tie a buntline hitch with one end of the lashing cord to the lifeline thimble/ferrule/etc. You can use other knots but the buntline is strong and compact.
2. Make your four round turns between the thimble and the pulpit. You want to try to avoid sharp bend radiuses. If possible, take the lashing around the full pulpit tube rather than just a bail, and if possible use a large radius thimble/ferrule/etc on the lifeline splice.
3. Pull on the tail to tension the lifeline, while smoothing the lashing and making sure all the strands have roughly equal tension. How much tension to pull depends upon the crew's preferences. Some crews like the lifelines as loose as the rule allows and others as tight as they can get them.
4. When you have the tension as you want it, secure the lashings with a whole bunch of half hitches. Some people cover the whole lashing with half hitches as chafe protection for it, but four half hitches are fine. Any of several more sophisticated constrictor knots can be used at the end of the half hitches, but they are generally not necessary.
5. Whip or sew the loose tail to one strand of the lashing. This is generally good practice but particularly necessary if you are using HMPE single braid, to absolutely stop it from slipping.
6. After you have used the lifelines for a couple days and are certain the tension is where you want it, wrap the lashing with tape. This makes it neater, protects it from UV and chafe, and further stops the half hitches from slipping.

The racing Offshore Special Regulations (3.14.6f) specify that the completed end lashings must not be more than 4" long. This rule is a holdover from the old 'wire-only lifeline' days. It does not add any safety to a HMPE lifeline (assuming the lashing is made to equal or exceed the strength of the lifeline), but it also does no harm to keep the completed lashings short. How much cord you need to make a 4" long completed lashing depends quite a bit on the bend radius at the ends, but a recent typical example required 54" of cord for each lashing (8 x 4" for the turns + 8 x 2" for the bends + 4 x 1" for the half hitches + 2" for the buntline).

Knots

Knots will weaken all lines, and can slip in HMPE line. Some knots are much more resistant to these two problems than others. So the best practice in HMPE line is to use these specific knots, secure them from slippage (sewing/whipping/tape), and use larger line size to compensate for the loss of strength.

Testing suggests that some common sailing knots are especially prone to slipping. A round turn and two half hitches slipped at 15 percent of breaking strength and a bowline slipped at 22 percent.

Testing (by the rock climbing and fire/rescue communities) suggests the [double fisherman](#) is a better alternative for joining two HMPE lines than the sheet bend, and that the [figure 8 loop](#) is a better alternative for making a loop than the bowline.

Offshore racers generally use splices with HMPE line, but have also had success attaching halyards and sheets to shackles and rings with the [bunt line hitch](#). The [halyard bend](#), usually with a figure 8 stopper tied on the end, can be used for attaching reef lines to the boom.

The tail of the knot should be stitched or whipped to the standing part as this will eliminate slippage. To untie these knots you can pull the tip of the tail away from the standing part and slice the stitches with a razor blade.

Moving up one line size will generally compensate for the loss of strength due to knots - 3/16-inch HMPE line has a tensile strength of about 5,800 lbs and ¼-inch line a tensile strength of about 8,500 lbs.

Specifically related to HMPE lifelines, it is US Sailing's strong recommendation that they be terminated at both ends with splices and NOT with knots.

Chafe protection

To minimize chafe, make sure the stanchion holes are smooth. If they have previously had wire life lines running through them they have probably been roughened up. You may need to take a fine file (or small dremel bit) and smooth them out and make sure there are not any sharp edges at the entry to the holes. Then take some very fine sand paper (300 grit) and give them a further polishing so that there is nothing to catch or cut the HMPE fibers. Be sure all metal edges in contact with the line are smoothly rounded and there are no sharp edges or weld splatter.

HMPE is one of the most chafe resistant fibers available. So, the single best way to further protect it against chafe is simply to use a larger diameter HMPE single braid line. This will be both extremely chafe resistant and easy to inspect. When HMPE chafes it shows quite visible fuzz on its surface.

If larger diameter line is not possible or desired, the second best method is to use a HMPE sleeve in the area of chafe. Any other method will likely be less chafe resistant than the HMPE and may hide any chafe on the HMPE from inspection.

Heat shrink tubing is a very distant choice for chafe protection. It is likely to chafe quite easily, and as discussed below requires care in its application.

Heat sensitivity

HMPE's one mechanical weakness is that it is sensitive to heat and will melt at relatively low temperatures (144°C). So, you should be extremely careful to keep the HMPE away from anything exceeding the boiling point of water.

Sometimes HMPE is sleeved with heat shrink tubing. This tubing will start to shrink at 90-100°C so it is possible to do this safely if done extremely carefully. But the typical heat gun has 400°C at its nozzle so it would be very easy to melt some of the HMPE fibers and weaken the line with a momentary lack of attention, and this might be invisible under the heat shrink. The best way to shrink heat tubing is in a carefully temperature-controlled oven, or to sit the line with tubing in a pot and pour boiling water on it. Do NOT put the line in a pot that is sitting on a burner because the metal can be higher than boiling temperature.

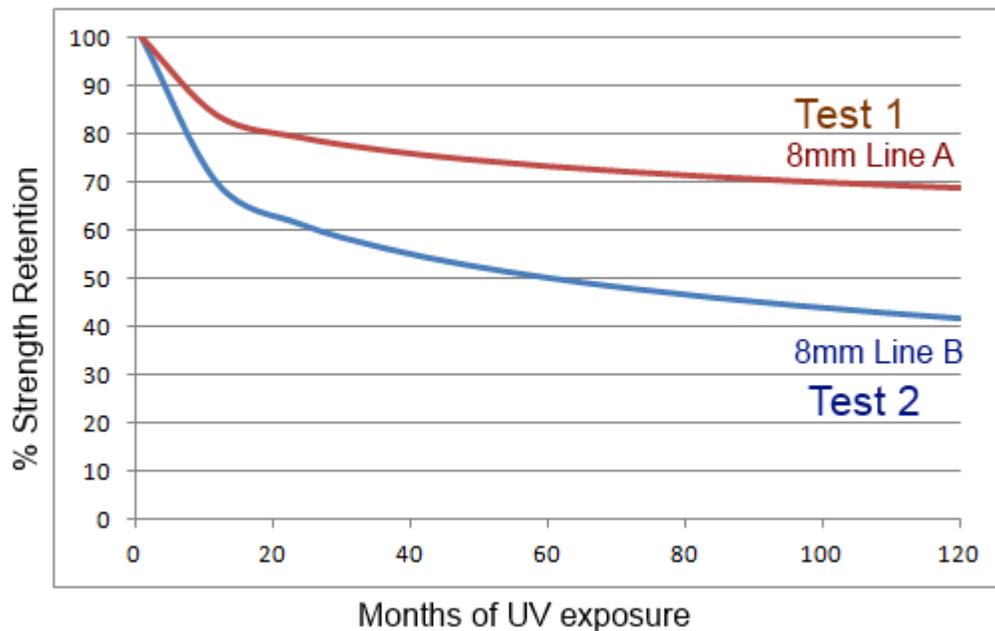
If you have your boat shrink wrapped during the winter, careless use of the propane torches used to shrink the plastic wrap can potentially cause problems. However, if done properly, with the torch always moving when near the lifelines, then it will not cause damage. However, the lifelines will melt if the torch is kept stationary on one spot or too close to the lifeline for too long. The safest thing is to untie the end lashings and completely remove the stanchions and life lines with them from the boat (because of the end splices its usually impossible to pull the life lines out of the stanchions and just take them alone off the boat). The second possible precaution is to have split hose cut to the lengths between your life lines and slip it over the lifelines before they shrink wrap, and this could help deflect any little slipups (but will not save them from a significant mistake in heat application). But again, if done with care, the shrink wrapping should not damage even unprotected HMPE life lines. Generally, if the shrink wrap is not melting, then the lifelines under it will not melt.

UV resistance

HMPE is one of the most UV resistant high modulus fibers. The line strength drops relatively rapidly during the first 18 or so months of UV exposure and then much more slowly after the surface of the fibers has been 'burned'. How much strength is lost will vary depending on the line's specific construction (diameter, braiding angle & tightness, type and amount of coatings) and the location (UV intensity). The graph below shows the results from two different tests (two different locations with two different lines, but both 8mm dia), which

bracket the likely strength loss (e.g. all the other empirical evidence falls between these two tests). This shows that HMPE single braid will lose about 20-35 percent of their tensile strength (leaving 65-80 percent of the original tensile strength) within 20 months of continuous exposure and at five years will retain about 50-75% of its tensile strength, and 40-70% at 10 years.

Impact of UV on Dyneema single braid line strength



Single braid line size (or double braid with the core exposed at the splices) should be selected to compensate for this UV reduction in tensile strength. 3/16-inch stainless wire has a tensile strength around 3800 lbs, while 3/16-inch HMPE single braid has tensile strength around 5,800 lbs. So, picking the same size HMPE as wire will roughly allow for equal strength after five years of intense UV. This is the basic philosophy used to determine the OSR minimum diameters.

Modern HMPE fibers offer a light and strong alternative to wire. By thinking through their installation and paying careful attention to their end terminations and minimizing chafe, they can be every bit as strong and safe as the wire lifelines they replace.