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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. 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.

There has been some confusion among sailors and riggers concerning these minimum diameters with double braid line - about whether the whole line or just the core must meet these minimums. The regulation's intent, and correct interpretation, and way that inspectors will proceed, is that the core alone should meet the minimum. So, for instance, a 5mm double braid with a 4mm core would only meet the 4mm minimum (and not the 5mm).

ISAF recently raised their minimums because of concerns about chafe. So, today there are two different versions of these minimum standards (ISAF and USSailing). For races run under the ISAF OSR's, these minimum's are 4 mm for under 28-foot LOA, 5 mm for 28 to 43 feet, and 5 mm for over 43 feet. For races run under the USSailing OSR's, these are 3 mm for under 30-foot LOA, 4 mm for boats to 43 feet, and 5 mm for over 43 feet.

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.

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, 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 has been some confusion about ISAF's recommendation that "Braid on braid (e.g. double braid) is recommended". The intent was to suggest that if your boat size requires a 4mm line/core, and you are trying to decide between a 5mm double braid line vs a 4mm single braid, then the 5mm product is preferred because it will offer greater chafe and UV protection to the loaded portion of the line. However, if you compare a 5mm double braid to a 5mm single braid (which will be more apples to apples - similar cost, weight and windage), then the 5mm single braid will start out almost 50% stronger and there is expert debate about which is preferred.

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. While the single braid is starting out with almost 50 percent more strength and it will suffer more damage from UV and chafe over time. The single braid will almost certainly be stronger for the first two years of use. After that there is not enough empirical evidence on this tradeoff yet and we do not know generally if or when the double braid option will become stronger. Of course with either option you should closely inspect the lines (particularly at each stanchion) at least annually and replace it when you see any significant chafe.

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 (http://www.neropes.com/SPL_12Strand_EyeSpliceBrummel.aspx) and the Bury (http://www.samsonrope.com/Documents/Splice%20Instructions/12Strand_C2_Eye%20Splice_JUL2012_WEB.pdf). 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 lock stitched or it may slip under very low load. With lock 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 (without lock stitching) 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. Recent testing indicates the buried tail must be at least 63 (and some recommend 72) times the diameter of the line, which is longer than previously recommended and typically used in practice. Both splices are acceptable, but the Bury splice is simpler and more resistant to improper construction, so it is generally used.

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 does expose the core to UV and Chafe at the splices. This is not super critical because the splices have two 'legs', and so the load on each is only 1/2 that on the line, but you can avoid this weakness by either covering the splice carefully with tape, or use a more complex splice (called a Core to Core splice:

http://www.neropes.com/Splicing%20Guide%20Individual%20Splices/CORE_TO_CORE_EYE_SPLICE.pdf,

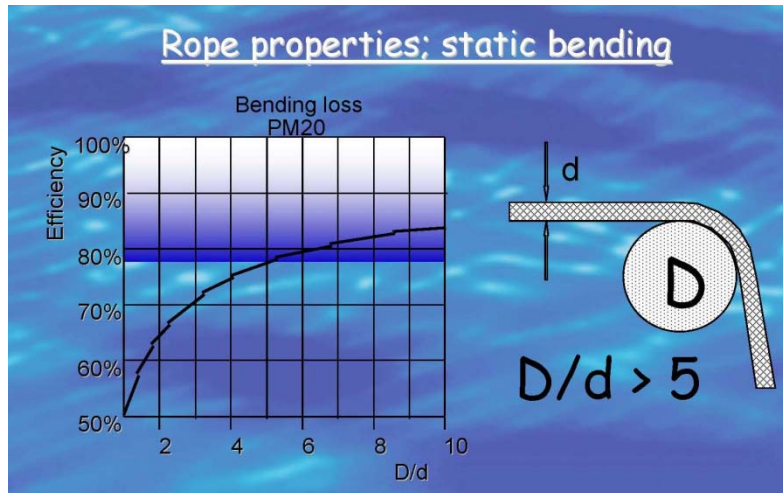
or

http://www.samsonrope.com/Documents/Splice%20Instructions/DbIBrd_C2_Eye%20Splice_AUG2012_WEB.pdf) which covers the core. These splices are more difficult than the single braid splice, particularly getting the necessary long bury driven home. But do not skimp on the bury as it is critical to the strength of the splice in these very slippery fibers.

One key 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. A second key to proper construction is that HMPE is more slippery than almost any other fiber and splices can slip at quite low loads if there is an oscillating or jerky loading. To prevent this splices should be lock stitched and the throat whipped.

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.



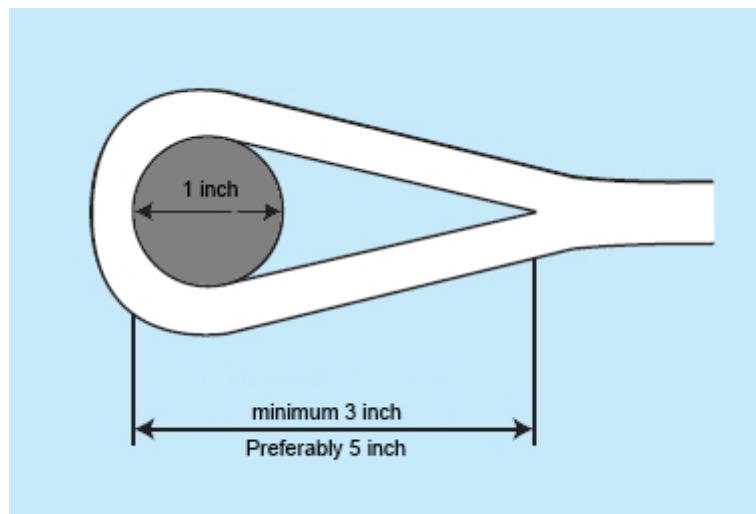
As the chart above shows, 1:1 bend radius (e.g. the bend radius is the same diameter as the line) causes these lines to lose roughly 50% of their strength. However, inside a splice there are two 'legs' carrying the load, with the load on each only 1/2 of the total, so you still have 100% system strength if there is a 50% loss at a 1:1 bend radius inside the splice. We have tested this, and if you join two spliced loops, they will typically break near the end of the splice taper and NOT at the 1:1 bend radius where they interconnect. Thus thimbles inside the splices loops are not required for 100% system strength, but (a) you must make sure that the bend radius is at least 1:1 particularly around small wire bails (not recommended in any case), and (b) thimbles do decrease chafe possibilities particularly if there is a lashing, so while not required, they are in fact good practice.

The HMPE lifeline should not be taken directly around the typical small diameter wire bails that are commonly welded on to pulpits, because of the possibility of weld failure.

This is not a perfect execution, but acceptable:



The one thing to be careful of when using thimbles is to keep the 'throat angle' at a minimum of 3:1 and preferably 5:1. Some "sailmaker thimbles" impose wide angles than that, which can weaken the splice at the throat.



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 between having enough leverage and friction to tension the lifeline and having too much bulk. 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 Dacron double braid, or HMPE core with Dacron cover or HMPE single braid. Dacron is more 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.

Recent testing has indicated that it is perhaps better to take the final half hitches only around the last single strand of the lashing, rather than around the whole lashing. This is because if you take them around the whole lashing, you clamp the lashing and prevent equal tension from coming on each strand and cut its strength by about 50%. Taking the half hitches around only the last strand allows the lashing to equalize tension between all the strands. It does make the half hitches more likely to slip, and you need to use at least 5 half hitches.

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 and unequal tension, so the cord should have a breaking strength of at least $1.3 \times 1,200 \text{ lbs} = 1,500 \text{ lbs}$. If you like HMPE-cored, 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 way follows:

1. Splice (or cow hitch a splice) one end of the lashing cord to the lifeline loop/thimble. You can use knots (water bowline is preferred) but if you do so, then you need to increase the "30% extra strength factor" to 50%. It should be noted that in HMPE single braid many of the common knots (for example bow line and bunt line) will slip under relatively low load - the figure 8 and water bowlines will not slip.
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 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 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 it has

not proven to be necessary. As mentioned above, recent testing suggests it may be stronger to take the half hitches around just the last strand rather than the whole lashing, but if you do so, you need 5 or more half hitches.

5. Whip or sew the loose tail to one strand of the lashing. This is useful if you are using HMPE single braid, to absolutely stop slipping.

6. After you have used it 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 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 as above 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. Use those knots, protect them from slippage, and use larger line size to compensate for the loss of strength.

Testing suggests that many 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, and a double fisherman slipped at 25%.

Recent testing suggests that the [figure 8](#) (or [figure 9](#)) and [water bowline](#) are the preferred fixed loops. The [EStar](#) knot is the preferred sliding/compact loop (the buntline will slip in HMPE single braid, even with a stopper knot tied in its tail). To join two lines together, either use these loops back to back or a [modified Carrick bend](#) (modified where you take the ends thru the center). The [halyard bend](#) (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 lock stitched 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 lock 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 prevent chafe, make sure the stanchion holes are smooth. Note: this is the single most important critical factor to make your HMPE life lines safe/reliable. They **must not** run over sharp edges or ridges at the stanchions, or they will be cut. 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 protect 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 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.

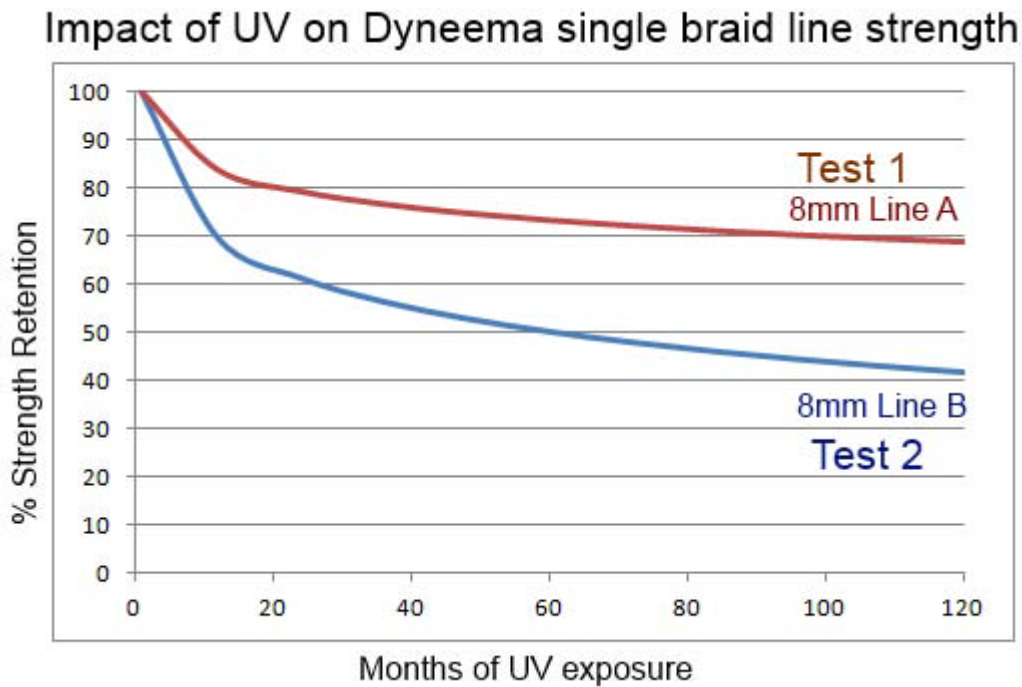
Sometimes HMPE is sleeved with heat shrink tubing. This tubing will start to shrink at 90-100°C so it is possible to do this safely if done extremely carefully. But the typical heat gun has 400°C at its nozzle so it would be very easy to melt some of the HMPE fibers and weaken the line with a momentary 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, the propane torches used to shrink the plastic wrap can potentially cause problems. If done properly, with the torch always moving, and with care for the lifelines, then it will not cause damage. However, they can melt the lifeline if the torch is kept stationary on one spot or too close to the lifeline for too long, and the surface of the lifeline gets hotter than 290°F (which would melt the shrink wrap also). 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 it's 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 they are not melting the shrink wrap, then they are not melting the lifelines.

UV resistance

HMPE is one of the most UV resistant fibers. The loss of strength depends on the line's specific construction (diameter, braiding angle, type and amount of coatings) and the location (UV intensity). The line strength drops relatively rapidly during the first 18 or so months and then much more slowly after the surface of the fibers has been 'burned'. As shown in the graph below (two different tests conducted in two different locations with two different lines, but both 8mm dia) they will lose about 20-35 percent of their tensile strength (leaving 65-80 percent of the original tensile strength) within 24 months of continuous sun exposure and at five years will retain about 50-75% of its tensile strength, and 40-70% at 10 years. It should be noted that that there is some very tentative test results that suggest that double braid covers allow a significant amount of UV thru to damage the core, and so double braid line does not eliminate this UV aging problem.



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.