The archaic future of standing rigging

BY CHRISTOPHER KINZEL

Top of the South Island, New Zealand, winter 2003, I was building the rig for a 63 performance/cruising sailing catamaran and looking for an alternative to steel for the standing rigging. As luck would have it, just a few orchards over was a large fishing port (Nelson) where Hampidjan, an Icelandic rope and net manufacturer, was selling this grey stuff that felt like rope but was reported to have half again the breaking strength of steel for the same diameter. I asked How much does it stretch?; It doesnt. they said. Interest was sparked, though many phone calls lay ahead of a decision.

I contacted everyone I could think of that might have had anything to do with Dynex 75. I asked other rope manufacturers, mast builders, riggers, engineers, composite rigging builders, sailmakers, ocean racers...
About its usefulness as standing rigging the response was mixed :
...wouldnt use it for the danger of chaffe ...sure we use it all the time ...the stuff creeps ...good for a rotating rigs shrouds but not on a fixed rig like yours ...to avoid creep youve got to over-spec. it (size) and youll be fine ...theres a whole world opening up based on what can be done with strong rope

- The weight savings would be huge.
- The rope vs. wire cost was about the same.
- The fittings cost would be less.
- The creep issue seemed avoidable , though difficult to monitor.
- The safety margin would be better.
- The termination and tensioning were design questions I would enjoy.
- The installation would be a bit time consuming but I could do it myself.

The base material is Ultra High Molecular Weight Polyethelene, refined by DSM in the Netherlands and marketed as Dyneema. Well known for some years now, it is sold to rope makers, sail makers, fabric makers world-wide. The fiber is also known as Spectra, Plasma, UHMWPE etc... Hampidjan adds a secondary heating/tensioning treatment, UV protective and abraision resistance coating, 12 braids, and markets it as Dynex 75. They have also done copious amounts of testing and comparisons with respect to tenacity vs. elongation, specific strength vs. specific modulus, creep, bending fatigue, abrasion, and UV resistance. They are the only Dyneema braider, (of the many), who are Loydds certified. Dealing with serious people, not just salesmen but the actual guys whod been trawling off Iceland with this rope instead of steel cable (testing ground and what!) helped bring my apprehension down to saner levels.

The rope was developed for trawling, towing, and mooring large objects. (see www.hampidjan.is). The manager handed me a product chart showing sizes up to 84 mm (3 3/8) that could handle 450 tons (what a relief to be at the small end of a vendors scale!). Not having any experience with sailboat rigging they were reservedly optimistic. Whether it was a foolproof choice, no one seemed to know for sure. To my mind, great potential was there, so I gave it a try. So far its not using me too hard.

Our vessel makes its rig work. Ive been told : 6 tons at the cap shrouds when flying a hull, 10 tons when you pitchpole. Ill bet for a short moment it could spike up higher than that. Weve punched along close reaching triple reefed doing 18 kts across about 35 kts true in a lumpy 3 meter chop... just checking ; not that we were looking to get into harms way, but charging the size of a tennis court through the stink and slop impressed us with a few big butty load sensations. The short of it is that the rig still stands, but maintaining tension has been an issue.

In this case the particulars are:

- LOA : 63 (19 m)
- Beam : 30 (9 m)
- Displ. loaded : 11 t
- Mast height off water : 88 (27 m)
- Rig style : fixed D section, double sweptback 30 spreaders (lowers almost full width of vessel) Capshroud load flying a hull full sail : 6 t Capshroud load flying a hull reefed : 8 t Capshroud load diagonal pitchpole : 10 t

Diameter Required

If breaking strength was the only determinant we could use a smaller diameter than a comparable 1x19 wire cable. However, the achilles heel of of the High Density Polyethelene seems to be cold creep: permanent deformation from a continuous load, measured over time (months and years) at a given temperature. Hampidjan has test data showing that a rope put under a load of 50% of its minimum breaking strength at 20C will creep past 10% (recommended elongation limit) after 7 months ; not a very useful length of time for holding up a mast. However when the sustained loads are at 20% of the minimum breaking strength at 20C (74F) for a year, 0.5% creep is encountered. A drop in temperature 10C (50F) will improve the time by a factor of 3 to 4. Easing shroud tension when not in use for extended periods can also help.

In my case riggers and mast builders said I could get away with 12 mm 1x19 ss wire, but be safer with 14mm cap shrouds. I chose 16 mm Dynex 75. The choice was made based on the predicted maximum sustained load while flying a hull, 6 tons which is 23% of the minimum breaking strength for 16 mm Dynex 75. Theretofore, after three years of flying a hull in 20C, we might see 1.5% creep (according to the charts). That would give us a useful life of 18 years of hull flying until we reached the 10% elongation limit. Weve been sailing about three months of the past year in the water and have yet to sustain flying a hull so Im guessing creepyness wont be an issue.

Weight Savings

The approximate difference between the rope I used and the cable I would have used is:

16mm DYNEX	125 m (410) x 16 mm (5/8)	DYNEX = 20 kg / 44 lbs

VS

14 mm WIRE	110 m (360) x 14 mm (9/16)	ss wire = 106 kg / 233 lbs

A weight savings of 86 kg / 189 lbs (or a factor of 5.25) !

Safety Factor

Using Augustina (63/19 m performance-cruising cat) as an example: in an ultimate dynamic loading situation (diagonal pitchpole) when relying on the minimum breaking strength of a shroud, the difference in safety factor is:

16 mm DYNEX	**2.8**
VS	
14 mm WIRE	**1.4**

Termination Design

A race is on with designers to come up with end fittings that will accommodate a pin connection, and or blend nicely an eye splice with a spar.
Some have tried the various wire end styles such as swagging, cone inserts, and cold casting, without success I was told, trying to improve on eye splicing rope may be like attempting to make a circle more round.

I found three styles of eye splicing twelve braid line. The weaving goes quite fast once one gets onto it, and they can be undone and repositioned.

The braid is loose enough to work without tools though the proper size tubular fid makes the job a laugh. Thanks to the UV protective coating the fibers maintain their bundles well. The simpler Brummel style takes minutes while the slightly stronger Tuck can take about an hour, with at least another hour if tapered, which offers the maximum strength and elegance. The third style involves twice the tucking, is trickier looking, but not as strong as the simpler over one under two tucking. Eye splicing is said to reduce a lines minimum breaking strength by 5-10%, while a Bowline will reduce a lines potential by 20-30%. A description of the Brummel and Tuck styles can be found on Hamidjans web site.

Splicing was the easy part. What to put the eyes around took a bit more mental effort. After much furious sketching: cheek blocks in the mast, splices around the mast, through the mast, through the spreader base... I resigned to make same-side external cheek blocks that hang on a heavy ss tube running through the spar. Agricultural but take-apartable, they seem to work alright, but I would prefer the splice not to have to bend (as it comes flat against the mast). Uneven loading, chaffe, and UV light are the obstacles. Perhaps a properly angled sheave molded or strapped on, or a solid thimble that split the eye fiber around the threaded stem of a standard in-the-mast ball joint / socket fitting. Eye diameter for Dynex (non moving) was recommended as a minimum 5 x the rope diameter to avoid fatigue.

Augustinas Cap shrouds run continuous from the hounds to the chain plates and back up to the upper spreader bases. The spreader tips are locked up and down by the diamonds which run in reinforced plastic hose over a molded groove. There are zero spreader tip parts. The

upper ends of the reverse diagonals are spliced into the cap shroud just above the spreader tips. In fact the upper diamond was added after the mast went up when we wanted more forward push (mast camber); no need to call a crane or a swaging guy or machine shop. The practicality was satisfying.

At the lower shroud ends we tried customizing standard rope thimbles by welding a bit of 1 1/2 ss pipe across the width to prevent collapse and to accommodate the tensioning lanyard. The chainplates were also made with the same pipe set perpendicular to the shroud axis. The chainplates work well but the thimbles tend to capsize causing the lanyard to pile up on one side causing uneven loading and making further tensioning impossible.

The rig was standing but the tensioning end system needed improving. The next major find was Precourt Systems, a Canadian outfit working specifically on developing fittings for synthetic rigging (see www.precourt.ca). They CNC
6061 T6 aluminum (anodized) into a range of deadeyes and thimbles that will accomodate stay sizes from dingies to 60 ft Multis.

As done thousands of years ago also works well today. Individual holes prevent the lanyard parts from binding. Following the perimeter of the shape with the lanyard hole pattern keeps the deadeye pointing in the desired direction (non-capsizing) balancing the load on the lanyard parts. The machining, styling and finish is smart, and the price very reasonable.

Changing over to those parts was a happy day for vessel and crew. A little design intelligence, is still going a long way.

Chaffe and Sun Protection

At the cheek blocks on the mast, pelican striker and spreader tips the Dynex passes through standard polyester braid reinforced plastic hose. This seems to handle the compression just fine as there is no abrupt loading at any surface. As for general toughness, its one of those ropes that does not cut easily.

When the original thimbles were taken off, the load bearing area of the Dynex appeared to have molded and melted such that the rope surface pulling against the thimble had become hard and smooth as glass. The boys from Hampidjan came down for a look. Though more interested in Augustinas Japanese fish net tramps, they quickly showed that a gentle massage could reduce the melted look back to soft fine fiber: condition normal.

Dynex is coated to defend against UV rays and abrasion. On a scale of Poor to Excellent, Dynex is rated as Good in its resistance to UV light. An independant study showed 15% strength loss after 3,000 hrs of exposure. It is also possible to recoat it. Parceling with self-amalgamating plastic tape would be cheap insurance. Better would be to use a polyester overbraided version (also adding protection against chaffe). Best is to overbraid after the eye splicing is done as the braiding can then be run up over the splice right up to the eye. This service should be had reasonably from any friendly rope braider. The cover will add slightly to an already larger than what is familiar (with wire) diameter, but I am told by mast designers that the weight savings (less pitching inertia) still beats out the added windage relative to performance.

Tensioning

In our case the 9 part lanyard (8 mm Dynex which amounts to a minimum breaking strength of 60 tons!) is led with snatch blocks to a winch. While tension is applied a bit of prying on the parts with a large screwdriver and fingers helps even up the load. Then with the sails up (dont go out the first time in much wind!) its easy to tack back and forth working the slack out of the leeward side. The lanyard starts by splicing to the lower deadeye, and the tail finishes at the upper deadeye by wrapping diagonally over the splice twice, and rolling hitches (at least four) around all nine parts. Under full tension there is enough advantage and friction in the lanyard to untie the hitches and still maintain the tension by hand (the hitches dont have to work hard). The next improvement was to install a turnbuckle in series with... the deadeye lanyards being the gross adjustment and the turnbuckle doing the final tensioning. This has proved satisfactory for keeping the mast in column, but we have never managed to get the headstay very straight. Though that may also be a function of the lack of a back stay and flex in the boat

Stretching

The Dyneema fiber does not stretch, however due to its being braided the rope will get longer when loaded. Compacting would perhaps be a more accurate term for the phenomenon of the increase in length due to off-axis fiber (braid) trying to straighten thereby compacting into a harder, and closer to nominal diameter (as it comes off the reel a 16 mm diameter measures close to 19 mm and compacts down to 16 mm once tensioned). As of yet, this is the most important issue, relative to using Dynex 75 for standing rigging. We have tightened and re-tightened the shrouds, (Ive lost track of how many times), the mast has stayed up, and now stays straight athwartships and keeps a nice forward camber. Any woven product will elongate as the fibers compact in their effort to straighten out. So just how much compacting until it stabilizes? It will stabilize after a season...

Measuring for length and splicing was done while the mast was horizontal. We started out with 2 feet (60 cm) of gap between deadeyes and are now down to about half that. Its been about a season of sailing and indeed the tension seems to be stabilizing. When we jump around in waves as loads spike there seems to be some give, which I would think is good to relieve stress.
However that give must be recoiling because Im not having to continuously tighten the shrouds anymore.

I put an 9 m (30) piece of 18 mm rigging on a test bed, gradually bringing the load up and then backing off. I was suprised to see the no stretch rope recoiling as the weave tightened and then relaxed. It seemed to do this less and less as the load was increased. Eventually a constant 10 t (30% the minimum breaking strength) was left on for three hours. The final elongation was about 4% with still a 0.5% recoil.

Erik Precourt has rigged 400 boats with rope, primarily multihulls with rotating rigs where some slack in the leeward shrouds is acceptable. He finds the useful life to be about the same as wire. He suggested that a wide staying base helps minimise the potential problems with stretch from stress, and that may be the reason our fixed rig, which relies on shroud tension for mast column, has put up with a bit of potential slack.

Just in

The good news is that Hampidjan has recently produced the next generation of Dyneema based rope ; they call it Dux. Through further heating under tension the twelve braided line is pre-stretched and firmer or more compacted, is spliceable just the same and is stronger than the Dynex 75 by up to 40% (depending on diameter). Ever notice how the more the handles of those supermarket bags stretch the stronger they become?

Summary

It may be we are returning to the days when fiber pulled and held for love or money. Perhaps todays materials and yesterdays techniques will create the rigs of tomorrow. On racing and more experimental boats the elimination of metal where possible is the rule: sails are lashed on, blocks are made with fiber and resin and lashed on, chainplates are fiber, masts are fiber, and standing rigging is plain rope.

There are several high strength rope materials to choose from: Dyneema, Kevlar, PBO, Vectran, each with its own advantage and inconvenience. The only thing they have in common is the way they dont stretch (much). Among those lines Dyneema/Dynex is a good choice because of its higher resistance to UV light and chaffe. It will also take a tighter radius at the splice, allowing for smaller thimble fittings.

Of course there are companies who build unidirectional synthetic rigging.
Fiber is wound from pin to pin and served, but at a much greater cost than a braiding machine can spit out rope.

Yes, replacing stainless wire with high strength rope is possible, but not in all cases. The potential for chaffe from hanks or furler gear would seem to rule out using it for headstays. In rigs such as multihulls with rotating wing masts, and traditional sailing vessels some rigging stretch is acceptable and welcome to relieve spike loads on the hull structure. Dynex 75 or Dux clearly offers a good improvement over wire for those rigs. For monohulls with short staying bases that require high shroud tension to keep the mast straight, Dux may be a solution. The bottom line is slightly more windage for less cost, and much less weight aloft.

As for longevity, the trawlers are replacing their lines after five years of hard service. I imagine that typical sailing rigs work a lot less. Though with time we hope to do further testing, know more, and will keep you posted.

Keep it light

Chris Kinzel
SV Augustina
Bay of Islands
NZ