What could Dyneema do for you?

When it comes to boats and rigging, we are surely no cleverer than our predecessors. What we have is better materials. Now if you subscribe to the view that classic boats result from a process of evolution (and also represent the leading edge of their day), then it makes sense to make best use of these materials. One obstacle is they are often introduced in such a fog of marketing hype, techno-babble and endorsements by handsomely paid celebrities that it can be hard to work out if they are actually any use. So here is my attempt to see how Dyneema, or Dyneema based rope might be used in traditional rigs.

To start with, what is available, and how does it compare?

Dyneema is a trade name of a high modulus polyethylene fibre, but it is rather more than. bits of a supermarket bag on steroids. It comes in four main varieties:

- a braided rope made from – usually - 12 strands of Dyneema which form a kind of tube. It looks a bit like pyjama cord, and is characterised by being light (it floats), very strong, low stretch, and happy to bend without much loss of strength. It is also slippery, so most normal knots don't work very well and it doesn't stay put in clutches and jammers. The slipperiness also means that it has to be carefully spliced (though the tube construction makes splicing pretty straightforward). It is not very good at resisting abrasion, so leads and fittings must be very smooth. There is also a variant which is heat-treated to make it stronger but less flexible. I'll call these **braided Dyneema** and **super-braided Dyneema** respectively.
- Then you can get that same rope with a braided polyester outer jacket. The purpose of that is to enable the rope to be gripped well by winches, jammers and clutches. To ensure the jacket is compatible with the inner core, the polyester outer tends to be woven very tight and hard.. Personally I find it rather unpleasant to handle directly. This is usually referred to as "**racing Dyneema**" or similar.
- One of the main snags with racing Dyneema ropes – aside from the feel – is the the cost. To alleviate this while retaining the low weight and stretch properties of the fibre, ropes usually referred to as "**cruising Dyneema**" have been developed where a centre core of Dyneema is bulked out with polypropylene and then jacketed with polyester. It is a kind of halfway house between braid-on-braid polyester and racing Dyneema.

So you have Dyneema in 4 generic flavours, super-braided,braided, racing and cruising. Their properties are summarised in Table 1 below, together with other types of rope used in rigging.

Table 1 Properties of various types of rope
(using 6mm diameter for comparison)

Item	Density – relative to water =1.0	Break Load (kg)	Extension 50% Load (%)	Extension at 500kg (%)
Wire ropes				
1 x 19 wire	7.0	2800	0.5	0.09
7 x 7 wire	7.0	2180	0.94	0.22
7 x 19 wire	7.0	2040	1.13	0.28
Dyneema based ropes				
Super-braided Dyneema	0.98	5040	2	0.2
Braided Dyneema	0.98	3980	2	0.25
Racing Dyneema	1.2	1800	2	0.56
Cruising Dyneema	1.2	1520	4	1.32
Polyester-based ropes				
Braid-on braid polyester	1.4	1230	5.5	2.24

Buff braided	1.4	590	12	10.17
3-strand Pre-stretch	1.4	1020	7	3.43
3-strand buff	1.4	550	17	15.45

The properties listed may need a bit of explanantion. They go as follows:

Density is clear enough so weight can be compared later on

Strength derives from breaking load in kg for a 6 mm diameter, but as we will see it is not always strength which is the crucial property

Stiffness relates to the extension – in percent – at 50% of the rated breaking load. For a new rope or wire rope there are a couple of things which contribute to stretch. First is constructional stretch, which is what happens as the fibres or strands settle down together under load and where splices or knots take up slack. The figure quoted here assumes that all this initial shaking down has happened, and so describes the amount of stretchiness you will be left with, which is inherent in the material itself.

Load bearing – just a comparative figure of stretch in % at a given load for a given size (in this case 500 kg and 6mm diameter. This relates the strength and stiffness of the wire or rope.

What it all boils down to is:

- steel wire rope is heavy, strong and very stiff
- dyneema-based ropes are light, very strong and quite stiff
- polyester-based ropes are fairly strong, not very stiff, and not very heavy.

Having seen what the various types of rope can do, we now need to turn to what we want them to do.In table 2 below I have ranked desirable attributes as follows:

- Paramount – if you don't achieve this you are wasting your time or money
- Important – the main features you seek
- Relevant – in the mix, but not with the same weight as the other attributes
- Not relevant – just like it says on the tin

Table 2 What you want rigging to do or be			
Attribute	Standing Rigging	Semi-standing	Running
	Shrouds & Stays	Halyards, sail controls	Sheets
Benchmark (for ordinary mortals)	Stainless wire 1 x 19	Stainless Wire 7 x 19 or Braid on Braid	Braid on braid
Strength	important	paramount	important
Stretch	Paramount	important	relevant
Weight	important	important	relevant
Cost	relevant	relevant	relevant
Size	important	relevant	relevant
Ability to cleat/hold	Not relevant	important	Important
Ease of handling	Not relevant	relevant	important
Flexibility	Not relevant	relevant	important

Remember that I've done this from the viewpoint of ordinary mortals rather than bleeding edge racers – so, for example, cost is always relevant! You may have different priorities, in which case

you will need to put your own slant on what follows. Whichever, now the task is to compare the needs with the available materials. Reducing to the minimum, your choice of materials for running rigging will be based on ease of handling, the semi-standing rigging requires strength and the standing rigging requires stiffness.

Standing Rigging

The whole point of standing rigging is to keep the spars in the same place. Without low stretch you are lost. So what you want is low stretch for a given load, and you can pay for that in terms of weight or size (or windage) or cost.

Table 3 How Dyneema compares with 1 x 19 Stainless wire rope				
1 x 19 wire as benchmark	Diameter for a given stretch	Weight for a given stretch	Diameter for a given load	Weight for a given load
1 x 19	1	1	1	1
Super-braided Dyneema	1.49	0.28	0.75	0.07
Braided Dyneema	1.68	0.35	0.84	0.09
Racing Dyneema	2.49	0.96	1.25	0.24

If you start with 1x19 wire as the benchmark there is no question that the best size for stretch is steel wire rope (see Table 3), so if you reckon windage to be the critical thing, then that is the one to go for. All the Dyneema rope diameters for a given stretch are larger. But if you worry more about weight than windage (i.e. you want stiffness for a given weight) then the various forms of braided Dyneema will be better than stainless wire rope by quite a margin, and will weigh maybe 10% of the steel equivalent.
So why do top race boats use fibre rigging? Well the stuff they use is both stronger and stiffer and lighter than steel based wire rope. Slight snag is that it is very expensive, and has about as much resistance to sunlight as Count Dracula, so it doesn't last long.
Remember too that Dyneema is stronger (size for size) than stainless wire rope, so substitution of Dyneema for 1 x 19 steel wire rope will be quite safe – plenty of strength in hand – but it will stretch more. Following from this, another point is that matching either size or stretch will mean that working loads in the fibre will be low, so splices or knots can be used even though they weaken the rope. Knots and terminals for these ropes will be looked at in a future article.

If however you are starting with 7 x 7 wire, the picture is a bit different (see Table 4).

Table 4 How Dyneema compares with 7 x 7 Stainless wire rope				
7 x7 wire as benchmark	Diameter for a given stretch	Weight for a given stretch	Diameter for a given load	Weight for a given load
7 x 7	1	1	1	1
Super-braided Dyneema	0.96	0.12	0.66	0.05
Braided Dyneema	1.08	0.15	0.74	0.07
Racing Dyneema	1.61	0.4	1.1	0.19

In terms of size, super-braided Dyneema of about the same size will weigh about an eighth as much for the same stretch. More weight saving is available if you could live with extra stretch. So you could change (or use this from the outset) but you could make a good argument for not doing so. One the one hand is the lower weight of the Dyneema, on the other the higher cost and reduced robustness.
Certainly carrying a length of braided Dyneema as an emergency stay would seem to make sense, but I'm not convinced of the need to get rid of my 1 x 19 wire stays.

Semi Standing rigging

Now let's have a look at the things which need to move but not all the time. I'm thinking here of halyards, running backstays, outhauls and other sail controls. The flexible version of wire – 7 x 19 - can be used to good effect and if it is then you can - as seen in Table 5 below - match the stretch with the same size of braided Dyneema with a big weight saving. If you aren't to fussed about the amount of stretch, and in this area it is classed as important but not paramount, then the extra strength – are you keeping up at the back? - of fibres like Dyneema can be brought into play, to use even smaller diameters and weights. Because it doesn't like being led around sheaves, I have not included super-braided Dyneema in these comparisons.
Just to give you the flavour of it – if you are using say 6mm 7 x 19 wire as a halyard, then you could match the stretch of that by using 6 mm braided Dyneema, or 10mm racing Dyneema, with weight savings of 90% and 70% respectively. If you were happy to allow a bit more stretch then you could use 4mm braided Dyneema or 6mm racing Dyneema. The weight savings are 94% and 83%. Yes you did read that right.

Table 5 How Dyneema compares with 7 x 19 Stainless wire rope

7 x 19 wire as benchmark	Diameter for a given stretch	Weight for a given stretch	Diameter for a given load	Weight for a given load
7 x 19	1	1	1	1
Braided Dyneema	0.95	0.11	0.72	0.06
Racing Dyneema	1.42	0.31	1.05	0.17

If your benchmark is braid on braid then a different set of factors comes into play (see Table 6). Say you wanted to replicate the stretch you get with a given polyester rope. The polyester stretches about 2.5 times as much as the modern fibres, so for a given stretch (i.e. lots) you could have tiny diameters of Dyneema. You are looking at a third the diameter, and a sixteenth the weight. That really is spectacular. Only one slight snag here, and that is that the Dyneema-based rope of that size wouldn't be strong enough.. As good an example as any of the difference between the **stiffness** needed for standing rigging and **strength** which is important for running rigging.

Table 6 How Dyneema compares with Braid-on-braid rope

Braid-on-braid as benchmark	Diameter for a given stretch	Weight for a given stretch	Diameter for a given load	Weight for a given load	Stretch at that dia & load factor
Braid-on-braid	1	1	1	1	1
Braided Dyneema	0.34	0.08	0.56	0.22	0.36

Racing Dyneema	0.5	0.21	0.83	0.59	0.36
Cruising Dyneema	0.77	0.5	0.9	0.69	0.73

Rather than trying to match stretch, a better approach may be to say you will use the same factor of safety in the rigging as you do at the moment. Even though you may not know exactly what that is, if your current arrangement works, then so will the new one. What happens now? Well for a given size of braid on braid – and I'm assuming the good sort here – your braided Dyneema can be 60% the diameter, and racing Dyneema about 80%. In both cases the resulting stretch will be about a third what it was, and the weight saving between 40 and 80%. Beyond that the blocks used could be smaller cheaper or lighter. Cruising Dyneema offers savings in stretch and weight, but not much in size.

What happens if the start point is ropes other than braid-on-braid polyester? Table 7 below summarises how racing Dyneema and cruising Dyneema compare with other types of rope commonly used in classics.

Table 7 How Racing and Cruising Dyneema compares with other ropes

	Racing Dyneema				Cruising Dyneema			
Start	diameter	weight	stretch	cost	diameter	weight	stretch	cost
Braid-on-braid	0.83	0.59	0.36	2.56	0.9	0.69	0.73	1.37
3-strand ps	0.75	0.49	0.29	1.77	0.82	0.58	0.57	0.94
Buff braid	0.57	0.28	0.12	1.12	0.62	0.33	0.24	0.6
Buff 3-strand	0.55	0.26	0.12	0.95	0.6	0.31	0.24	0.51

With racing Dyneema you are looking at around ¾ the diameter and a half the weight. But you may have to change the hardware (jammers winches etc.) to cope with this. This is where classic boats with cleats, belay pins etc. can win over modern ones with jammers and clutches sized for a particular rope. This aspect will be the subject of a following article.
You can see that the savings in either size or weight or stretch which can come from the replacement of buff braided and 3-strand ropes are quite compelling. What is more the replacement may even cost less.

I should say that the cost column needs to be treated with a bit of caution because the savings may very well be overstated:

- unlike material properties, prices may vary widely.
- You may not practically be able to realise the potential saving. For example, even if you are using 12mm rope now and the sums indicate that 9.2 mm rope will do, you can't buy it in that size. In the likelihood that 8mm would be a leap too far, you would have to go for 10mm.
- It may be that your hardware will not suit a smaller diameter.

But when even cruising Dyneema offers lower size, weight and stretch at lower cost for everything except the best braid-on-braid, what is there not to like? I think this is where these new ropes really come into their own. Subsequent articles will look at the practicalities of changing over.

Running Rigging

And of course that would apply to running rigging, where you need to be tweaking all the time. Maybe not. I'm going to make the bold assumption that the actual size of the rope you currently use as sheets is OK – in other words it is comfortable to hold, strong enough, and the right size for cleats, blocks winches and other relevant hardware.
In other words for running rigging (sheets etc.) I'm saying that size is the most important attribute of the rope. Now size for size, racing Dyneema is about 4 times the cost of polyester, and cruising Dyneema about twice. Sure, the weight will be reduced by about 15% and the stretch by a good deal more than that, but is that critical for a piece of rope which you can trim? Well it is your call, but for my money I'll stay with polyester.

To sum up, then.

Standing rigging – braided Dyneema is a perfectly credible substitute for 7 x 7 wire (and great as emergency rigging because it is so easy to splice and store) but is either bigger or stretchier than 1 x 19. I'm not sure it is really worth the candle here. You never use the full strength of Dyneema if you want to maintain the stiffness of the rig, and stiffness is the main idea.

Semi-running rigging – this seems to me the main area of application, particularly on gaffers where there is string everywhere, so the saving of weight and windage, not to mention the possibility of even saving money, are pretty compelling.

Running rigging – sheets etc. – I can't see the point because if you are constrained by hardware or comfort to a particular size of rope then the cost is necessarily a good deal more, and the benefits harder to identify. But if starting from scratch, and you use more winches than hands then you can see how Dyneema-based ropes could feature to advantage.

The next article(s) will be looking at the practicalities of converting to Dyneema-based ropes.