WEIGHT-OF-THE-ART

IF YOU THINK YACHT DESIGNERS ARE OBSESSIVE ABOUT WEIGHT PLACEMENT, YOU'RE RIGHT. HERE'S WHY.

By Guy Waddilove

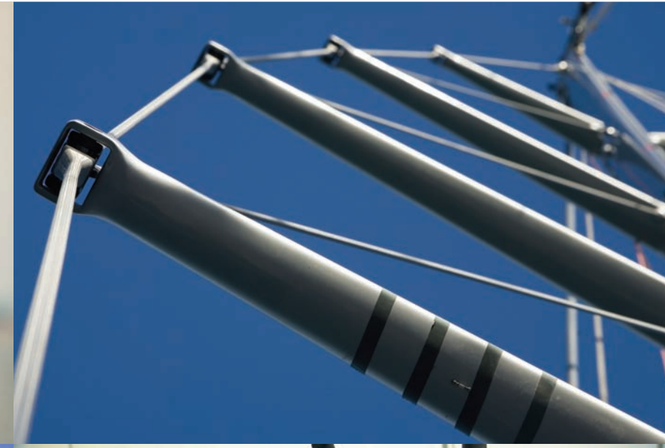
Renowned sailing boat designer Uffa Fox famously commented that the only place for weight is in a steam roller. When talking about sailing yacht performance in simple and very general terms, weight is inversely proportional to speed: add weight and sacrifice speed, remove weight and go faster. Designers and yacht builders continually strive to save weight to improve performance, and the continual development of hi-tech materials allows significant weight savings to be made without sacrificing strength or safety.

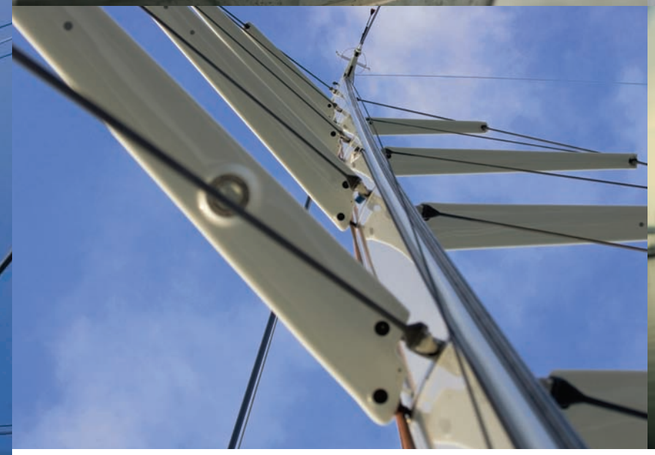
While overall weight in itself is important, what is of more interest to yacht designers is the actual position of the weight on the yacht. If weight is added aloft, the weight has to be counteracted by adding weight lower down in the vessel as the centre of gravity will have moved upwards. When the centre of gravity moves up, the righting moment -the ability of the vessel to return to upright - is reduced. One way of visualising this is to imagine climbing the mast of a sailing dinghy: as you climb higher, the centre of gravity moves higher until you capsize. So you're better to keep the weight low.

Conversely, if weight is reduced aloft, the yacht's centre of gravity is moved downwards, which will have the effect of increasing the vessel's righting moment. The advantage of this increase in righting moment can be used in several different ways depending on what the designer or yacht owner wants to achieve.

Yachts that race can benefit from reducing weight aloft. When the righting moment is increased by reducing weight in the rig, weight can be shaved off the keel bulb. So not only do you have lighter rigging, you also get a lighter keel and a faster boat. An alternative performance enhancement that reducing rig weight would allow would be to increase the height of the mast instead of reducing the weight of the keel bulb. This would provide for more sail area and therefore a more powerful rig. An alternative that could better suit cruising sailors less concerned with speed is to use the increase in righting moment to reduce the draft of the keel giving them the advantage of access to shallow waters.

Another advantage of having less weight aloft is that the heeling angle of the yacht is reduced. If you imagine an 80kg man swinging from the top of the mast while the yacht is sailing heeled over, bringing him back down to deck would obviously return the yacht toward upright. Through choppy seas or waves, a reduction in rig weight will also result in a reduction in pitching giving a more comfortable motion. As well as a smoother ride, the reduction in pitching means less shock loads on the rigging as the yacht pounds into head seas.





Over the last two decades, sails and masts have benefited from the application of hi-tech materials for increased strength and reduced weight. Sails have become lighter and stronger with the inclusion of fibres such as carbon, Vectran, Spectra and Technora, while carbon fibre masts are now commonplace across yachting as a carbon fibre mast weighs approximately 60 per cent of its equivalent in aluminium. The next logical place to start lopping weight aloft is the standing rigging.

The use of composites in standing rigging creates various challenges for designers and manufacturers. Choice of suitable materials and the issue of terminating rigging sections were the two major areas that needed to be addressed.

Currently PBO and carbon fibre are the two main materials being used for composite rigging. Kevlar is also used but to a much lesser extent because of its tendency to creep over time.

PBO, or to give its proper name, poly(p-phenylene-2,6-benzobisoxazole), is a very high strength, low stretch synthetic polymer also found in bullet proof vests, the cockpits of Formula One racing cars, tennis rackets and NASA's Mars exploration vehicles and it is the predominant material currently used in composite rigging. It has been dubbed the world's strongest fibre, with a tensile strength approximately 10 times that of steel, a 1mm thread of PBO can hold a weight of 450kg.

Carbon fibre is now a widely accepted composite used in a huge variety of applications because of its strength-to-weight ratio. The strengths and limitations of carbon fibre are well known and proven in the marine industry.

With respect to terminating sections, two schools of thought have developed. One of the techniques adopted uses continuously wound threads of PBO fibre around thimble fittings to form slings. The other technique uses compression fittings where the ends of preformed lengths of composite cable are splayed around a male cone with another female cone fitted over the top to form a friction or compression fit. Various adaptors and fittings can be screwed into the compression fittings when formed.

A number of companies have developed systems for yacht composite rigging including Future Fibres, Southern Spars, Ocean Yacht Systems (OYS) and Navtec.

Future Fibres is one of the companies leading the field in composite rigging development. After moving ashore from a career in yachting, company founder Tom Hutchinson realised the potential of using hi-tech materials for standing rigging, initially for racing yachtsmen and subsequently the whole yachting industry. Hutchinson set up Future Fibres to develop a composite rigging system that utilises continuous wound PBO strands. With Future Fibres's rigging, the PBO fibres are laid parallel and wound in a loop at an equal tension to ensure equal load sharing amongst the fibres. Because PBO can be degraded by moisture, ultraviolet light and salt crystals, it is encased in a sheath to give protection after the section is wound. The sheath also acts to pull the fibres of the core together ensuring an even load spread between fibres as well as minimising the diameter of the bundle. For terminations at the deck

and spreaders, Future Fibres uses thimbles at either end of each section with the PBO fibres forming a continuous loop around the thimbles to form a sling.

Future Fibres claim that their rigging is up to 80 per cent lighter than Nitronic® rod rigging as, not only are the cables lighter, the terminations using thimbles and a single pin are also considerably lighter than the tip cups that would be used with rod rigging or compression terminations. Additionally, the rigging can be custom manufactured to any given specification for break strength and diameter.

In terms of reliability, Future Fibres point out that their rigging was used successfully by all of the entrants in the punishing 2006/7 Volvo Ocean Race. For performance, almost all of the last America's Cup syndicates chose to use Future Fibres rigging.

Both Navtec and OYS, historically the leading rigging companies that produce Nitronic rod rigging, are also producing PBO rigging. OYS is using compression fittings to terminate lengths of pre-made PBO cable. By terminating in this manner, sections of PBO cable can be retrofitted to rigs not originally designed for composite rigging as the compression fittings are sized to match the fittings that rod rigging uses. Changing over from rod rigging to PBO is therefore relatively straight-forward as no modification is needed to the deck fittings, spreader tip fittings or mast tangs. OYS replaced the nitronic 50 rod on the 80ft Swan *Maligaya* with PBO composite rigging. The weight of the original Nitronic rod rigging was 525kg compared to 150kg for the PBO rigging that replaced it. No alterations were made to the mast and spreaders and the rod was removed intact and therefore could theoretically be used again. An advantage of using compression fittings rather than the sling-wound style is that it is cheaper to manufacture as the pre-formed cable is taken off a reel; the only process involved is the fitting of terminals.

Navtec opened a facility to produce continuous wound PBO rigging last year which they are marketing under the name Z System. Up until this point Navtec had concentrated on producing PBO cables that terminate with their bi-conic compression fitting system. Now that the company can offer both techniques, they can combine the techniques in a hybrid of the two systems with a Z System sling style thimble at one end of a section and a bi-conic fitting at the other. This hybrid offers the strength advantage of wound slings and the ability to retrofit to rigs originally set up for rod rigging.

Southern Spars has taken a totally different approach to composite rigging solutions utilising carbon fibre with its Element C6 system. With Element C6, standing rigging is formed from bundles of pultruded carbon fibre strands that are encapsulated in a sheath. The rigging is similar in some respects to conventional wire rigging but without the twists. Southern Spars has used this bundling technique as the advantageous properties of carbon fibre of strength, weight and low stretch are well known, but previous attempts at reliably terminating carbon fibre rods were not successful. Head of Southern Spar's Composite Rigging division Scott Vogel points out:

"Carbon is a base element - there's not that much more you can do with it - it has already been burned! So the fibre is pretty inert environmentally, it doesn't really care about moisture or UV or any of that stuff which some of the other fibres have a problem with."

Carbon fibre rigging is not as light as PBO but it still offers a large weight saving when compared to nitronic rod. Southern Spars cites a 400kg weight saving in rigging on a 100ft Swan that it fitted with Element C6 rigging compared to that of Nitronic rod.

A further development of Southern Spar's carbon rigging is Element C6+. Element C6+ is in some ways a throwback to earlier rigging techniques in that it is continuously rigged. Continuous rigging is where each piece of rigging goes from the deck fitting to a tang on the mast, as opposed to discontinuous rigging where separate vertical pieces of rigging run between each spreader and separate diagonal pieces of rigging run between spreader tip and mast. Continuous rigging does away with terminations at the spreader tips meaning that lower profile spreader tips can be designed which produce less drag. Weight is also saved as less termination fittings are required with continuous rigging.

Composite rigging offers performance benefits for racing sailors and cruising sailors alike. As well as the previously mentioned benefits to performance, using lighter rigging makes it easier for riggers to manhandle sections, and where cranes were previously used for dressing larger masts, a yacht's own halyards can be used to fit rigging sections. Composite rigging is also cheaper and easier to transport because of its lighter weight and in most cases sections can be picked up by hand, which would not be possible for some of the larger nitronic rod sections.

Composite rigging is now being adopted right across the sailing industry from club sailing yachts to 148ft superyachts. As is the case with most developmental technology in sailing, particularly with hi-tech materials, what started as an expensive prototype concept seen only on large budget sponsored racing yachts has quickly filtered down to benefit the whole yachting industry. O