CARBON YACHT SPARS

SELDÉN
for sailing

A NEW GENERATION OF SUPER LIGHT PERFORMANCE RIGS

REASONS WHY YOU WANT A CARBON MAST

1. Lighter rig. Weight saving on the bare tube of up to 50%, saving on a complete mast (excl. rigging) approx. 40%. Overall weight on the complete rig is reduced by 25-35%.
2. Lighter rig = lighter boat = FASTER (especially in acceleration out of tacks).
3. Lighter rig = reduced heeling moment = potential for smaller keels = even lighter boat = EVEN FASTER.
4. Reduced pitching moment in waves due to lower centre of gyration of the boat = FASTER.
5. Tailoring of tube stiffness to suit specific requirements (e.g. stiff mast between forestay and backstay to give more direct load transfer if required).
6. Stiffer tubes. Enables higher rigging loads for more controlled forestay tension (see test case example).
7. In most rating rules, the penalty for using carbon is less than the potential performance gain. YOU WIN RACES AND YOUR BOAT IS WORTH MORE MONEY.

REASONS WHY YOU WANT A SELDÉN CARBON MAST

1. The process of CNC filament winding pre-preg carbon tow is unquestionably the most consistent method of carbon tube manufacture. Computer controlled lamination using tow with only a 2% variation in resin content, autoclave cure at up to 7Bar for ultimate laminate consolidation.
2. Lowest possible resin content.
   More fibre, less resin = lighter, stiffer masts.
3. Sections mirror the new Seldén C profiles, optimised for longitudinal stiffness to maximise performance for modern fractional rigs.
4. Great interchangeability with existing Seldén alloy spars. Many shared components like the adjustable T base and deck rings.
5. Optimised fibre angles to produce tubes with the best balance of longitudinal, torsional and hoop strength.
6. Option of customised laminates to give a complete ladder of inertia options (see page 10).
7. Carbon masthead cranes and boom brackets.
8. U/V clear coat varnish finish as standard, plus the UV inhibitor built into the resin provides excellent protection against the elements.
9. Custom track for boltrope or RCB car option on the same track.

TEST CASE FIRST 36.7

A new Seldén carbon mast was fitted to BengtFalkenberg's First 36.7, we asked him some questions on the performance of the rig:

Seldén - What were your first impressions of the mast?

BF - Very good looking, seeing the fibres in the clear finish is good. Regarding the set up, we immediately noticed the carbon mast was significantly stiffer despite being the same section size as our alloy rig.

Seldén - What was the effect of this increased stiffness?

BF - Well, we could wind the carbon mast up much more transferring significantly higher loads into the forestay. This was really fast as we maintained a fine jib entry in medium and heavy air.

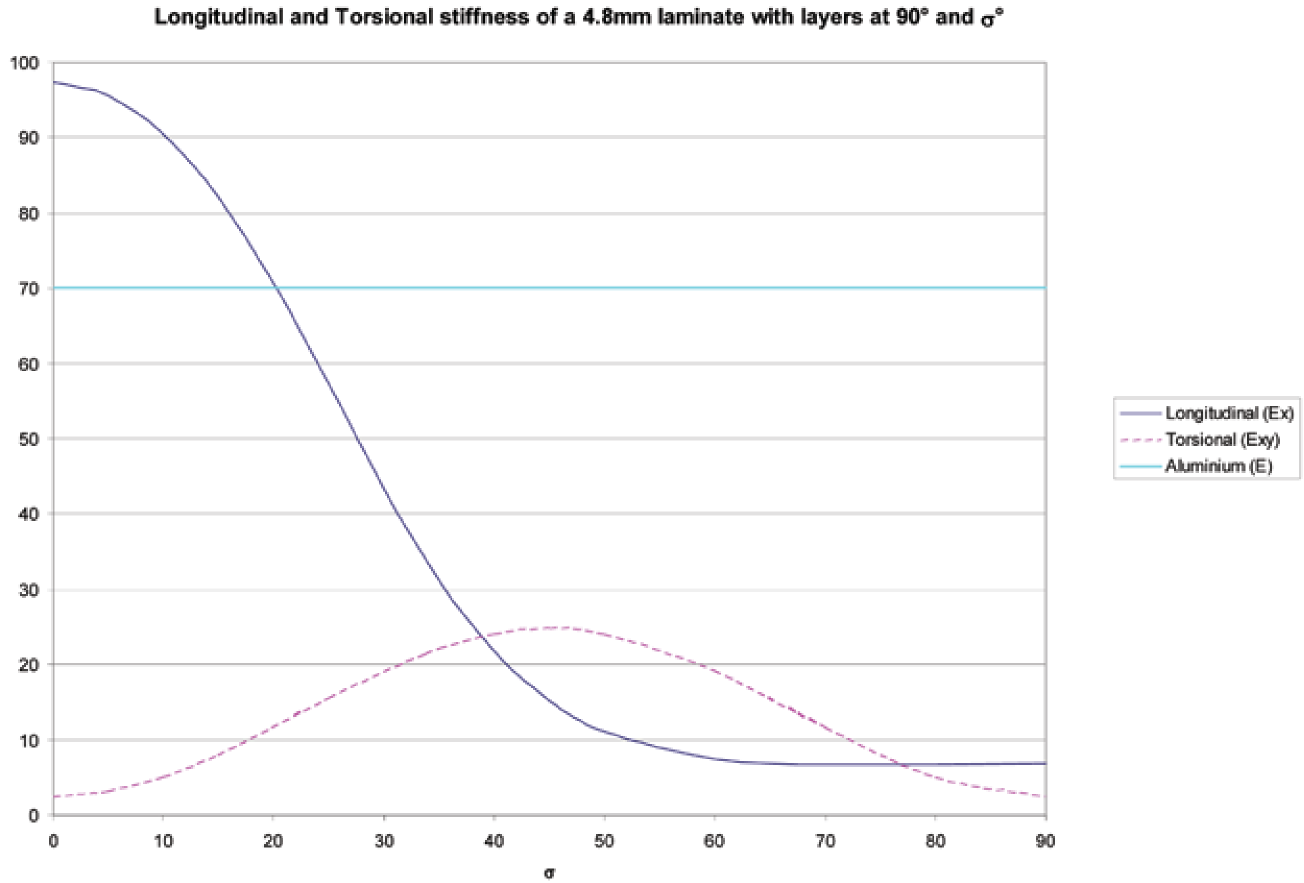
Seldén - What about the mainsail set up?

BF - The mast was straighter so we could make a mainsail with less luff curve and more optimally located seam shaping with a larger roach. The rig was just better, fine jib entry and a better, larger cut mainsail.
THE BOAT WAS FASTER.

Seldén - When did you notice the biggest difference?

BF - All round really, we were fast in light winds with the bigger roach main, fast in the heavy air due to maintaining the fine jib entry, but I guess biggest speed difference was in light winds/choppy sea. The boat felt like it pitched less, I guess due to the lighter rig, we were a rocket ship in those conditions.

CARBON VS. ALUMINIUM



Carbon fibre is an anisotropic material, this means it is extremely efficient when working in the designed direction, but relatively poor in any other direction.

Aluminium alloy is isotropic (average in all directions).

To optimise a carbon mast we have to 'lay' the fibres in a cleverly designed 'laminate' to produce a tube that can give us all the characteristics the spar will require (i.e. longitudinal, torsional, hoop strength and stiffness).

Seldén have researched the optimum fibre angles to generate the resultant stiffness for ultimate stiffness and performance. In filament winding we can laminate any angle from 5° to 90° (angle to zero axis), and add 0° fibres manually when necessary. However our competitors will claim that our masts are not as good as theirs because our fibres are not laid at 0°. This is not true. Their claimed performance is theoretical, which is rarely achieved in the final laminated product for the following reasons:

Resin and void content

Factors such as resin and void content have a dramatic effect on the strength of the laminate. The resin content in pre-preg tow is far more accurately controlled than in wet lay up or infusion processes so the laminate strength is maximised.

The resin cure cycle is also very important in maximising the strength of the final structure. An autoclave has a very sophisticated ramp cycle and pressured cure, which virtually eliminates voids from the laminate. Voids are effectively holes and a high void content will dramatically reduce the laminate strength. (Autoclave cure is essential on profiled laminates).

Orientation of the fibres

The accuracy and orientation of the fibres laid down will also govern the performance of the laminate and in pure compression terms you will get a fall in performance if the fibre is even slightly off axis. However a percentage of off axis fibre will always be required to stabilise shape and allow for torsional loads.

We commissioned independent research and testing in early 2002 to analyse laminate structures. They confirmed that when carbon fibre is working within a laminate structure, to achieve optimum performance in both longitudinal and torsional stiffness fibres could be laid down at between 8° to 21° degrees depending on the degree of torsional stiffness required while still exceeding strength requirements.

Using this information we have optimised our winding process to ensure greater accuracy of angle as well as perfecting techniques to wind different angles through the length of the spar to maximise stiffness and bend in each panel. This process combined with local hoop and patch reinforcements provides really light, stiff and robust carbon spar sections.

Conclusions

It is not important whether the laminate is constructed with 0° and +/-45° fibres or with “off” axis fibres - the required weight, strength and stiffness for a performance spar can be achieved either way.

What is critical is that:

- The orientation of the fibres is accurately controlled - it should not be done by hand.
- That the resin content is accurately controlled and is as low as possible.
- That the laminate is well consolidated with close to zero void content (cured in an autoclave).

Southerly 46 powered by Seldén carbon mast.
Photo courtesy of © Northshore Yachts

CARBON EXPLAINED

Seldén section structure

All Seldén sections are filament wound. Each section is available in two wall thickness's with additional reinforcement of Uni-directional tape in key strength areas (tapered top masts for example) gives us 6 inertia options per section size. This extensive set of options enables us to optimise the inertia ratio for specific requirements.

Seldén Process

Individual carbon fibres are very light but fragile. For their weight, they are very strong in tension. To make a structure, the fibres are brought together and held firmly in resin. To help handling, the fibres are made into different types of raw materials for manufacturers of large components. We use four types of raw material:

a. Pre-preg Tow. This is thin ribbon made from bundles of plain fibres held together by uncured resin.

b. Pre-preg UD Tape. This is a wide tape formed in the same way as tow. Applied externally by hand in long strips.

c. Pre-preg cloth. A woven cloth made from tow. Applied externally by hand in multi layer reinforcement patches.

d. E-glass. Pre-peg fibreglass used internally as an insulating layer where aluminium components may be fitted.

Manufacture

The basic tubes are wound over a male mandrel. The mandrel rotates on a large 4 axis CNC lathe, and a delivery head moves in a pre-programmed pattern along a track to lay fibres onto the surface.

The pre-preg carbon tow is applied under tension, the layup pattern is driven by a programme which interprets the mast requirement. Layers are built up at various angles to the mandrel axis. UD tape and reinforcing patches are applied during the filament winding process.

At this stage, despite the tow being wound under tension, the layup is not consolidated. If heated at this stage it would produce a relatively low density laminate. The secret to making a strong laminate is to apply the correct pressure to squeeze the laminate together at the same time as applying heat to cure the resin. To do this, heat shrink tape is wound onto the outside, using the filament winding head. The whole mandrel/laminate/heatshrink tape combination is then put into a vacuum bag and setup for cure in the autoclave. The temperature and pressure are increased, maintained and then reduced in a tightly controlled manner.

As the temperature increases, the mandrel expands and the tape shrinks. This, together with the increased pressure from the autoclave, squeezes the laminate as it cures with the heat. The resulting laminate is really well consolidated, with virtually no void content.

The cured assembly is allowed to cool, removed from the autoclave, then removed from the mandrel using hydraulic power.

Photo courtesy of © robrowephotography.co.uk

Fittings

Having similar dimensions to the new alloy sections means that we will be able to use the same heel fitting and deck ring for both aluminium and carbon masts. Insulation on these items is not a problem using e-glass or mylar tapes.

The external sail track incorporates a central boltrope groove.

Plant

The new UK factory has a 20m autoclave at it's heart, and the current filament winding machine has been extended to match. They will allow one piece sections to be made up to 19.3m long.

Above this length sections can be joined. Special joining sleeves have been developed that minimise weight and have a neglible effect on local stiffness.

COMMONLY ASKED QUESTIONS

How much extra will they cost?

As the carbon mast can be optimised, direct cost comparisons are difficult. Our selling prices are very competitive in the market, especially for the given performance.

Can they be tapered?

There are standard parabolic tapers for fractional rigs. Each reduces the section f&a dimension by 33%.

Do holes weaken the structure?

Yes. Holes may only be cut where the mast is suitably reinforced and should be fitted by a person with experience in composite materials.

Can it be painted?

Yes and yacht spars are painted with clear U/V varnish as standard.

How difficult is it to repair?

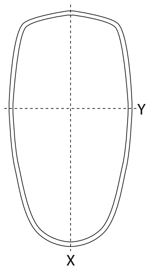
Not difficult. The repair must be done by a person skilled in composites.

Can extras be added?

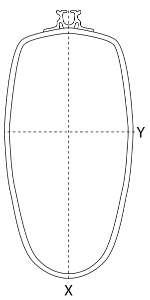
Yes. But reinforcement is required. Additional reinforcement may be added after manufacture, but the best method is to include extra reinforcement when the tube is made.

MAST SECTIONS

Detailed below is our carbon mast section range, where the section shapes have been developed along the performance principals of the new alloy range. With the opportunity to customise laminates, we can offer a complete ladder of inertia options to suit all requirements.



Section	Dimensions X/Y	Ely (GNmm^2)	Elx (GNmm^2)	Wall thickness (mm)	Weight (kg/m)	Wy (cm^3)	Wx (cm^3)
CC154-30	157/87	230	92	3.0	1.8	40	30
CC154-36	158/88	292	117	3.6	2.2	49	37
CC174-30	177/93	325	120	3.0	2.0	51	37
CC174-36	178/94	411	152	3.6	2.4	61	44
CC192-36	195/102	533	194	3.6	2.6	72	52
CC192-42	196/103	644	235	4.2	3.1	85	61
CC210-36	213/110	688	242	3.6	2.9	85	61
CC210-42	214/111	832	293	4.2	3.4	100	71
CC226-36	228/118	849	301	3.6	3.1	98	70
CC226-42	229/119	1025	365	4.2	3.6	115	82
CC244-42	247/127	1282	448	4.2	3.9	134	95
CC244-48	248/128	1503	527	4.8	4.5	153	109
CC263-48	266/136	1844	638	4.8	4.8	176	124
CC263-54	267/137	2116	735	5.4	5.4	199	140
CC284-48	286/146	2314	800	4.8	5.1	205	145
CC284-54	288/147	2653	920	5.4	5.8	231	163
CC303-54	306/156	3203	1107	5.4	6.2	262	185
CC303-60	307/158	3613	1253	6.0	6.9	292	206



	Including track 1) 2) 3)		Including track and 1x300gsm 100mm wide 0° tape front & back		Including track and 2x300gsm 100mm wide 0° tapes Front & Back	
Section	Ely (GNmm^^{2})	Weight (Kg/m)	Ely (GNmm^^{2})	Weight (Kg/m)	Ely (GNmm^^{2})	Weight (Kg/m)
CC154-30	302	2.3	335	2.4	365	2.5
CC154-36	367	2.7	399	2.8	432	2.9
CC174-30	418	2.5	460	2.6	501	2.7
CC174-36	508	2.9	550	3.0	594	3.1
CC192-36	648	3.1	699	3.2	751	3.3
CC192-42	763	3.6	815	3.7	867	3.8
CC210-36	824	3.4	887	3.5	951	3.6
CC210-42	972	3.9	1036	4.0	1099	4.0
CC226-36	1005	3.6	1078	3.7	1152	3.8
CC226-42	1185	4.1	1259	4.2	1335	4.3

	Including track 1) 2) 3)		Including track and 2x300gsm 100mm wide 0° tape front & back		Including track and 4x300gsm 100mm wide 0° tapes Front & Back	
Section	Ely (GNmm^^{2})	Weight (Kg/m)	Ely (GNmm^^{2})	Weight (Kg/m)	Ely (GNmm^^{2})	Weight (Kg/m)
CC244-42	1467	4.4	1641	4.6	1812	4.7
CC244-48	1691	5.0	1868	5.1	2044	5.3
CC263-48	2061	5.3	2264	5.4	2470	5.6
CC263-54	2336	5.9	2542	6.1	2750	6.2
CC284-48	2564	5.6	2804	5.8	3041	6.0
CC284-54	2907	6.3	3150	6.5	3393	6.7
CC303-54	3488	6.7	3762	6.9	4034	7.0
CC303-60	3901	7.4	4180	7.6	4458	7.7

Southerly 46 powered by Seldén Carbon Rig.
Photo courtesy of © Northshore Yachts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The Seldén Group is the world's leading manufacturer of masts and rigging systems in carbon and aluminium for dinghies, keelboats and yachts.
The Group consists of Seldén Mast AB in Sweden, Seldén Mast A/S in Denmark, Seldén Mast Ltd in the UK, Seldén Mid Europe B.V. in the Netherlands, Seldén Mast SAS in France and Seldén Mast Inc. in the USA. Our well known brands are Seldén and Furlex. The worldwide success of Furlex has enabled us to build a network of over 750 authorised dealers covering the world's marine markets. So wherever you sail, you can be sure of fast access to our service, spare parts and know-how.

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