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# Carbon Spars 2002

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## Introduction

The Flying Dutchman class has been considering allowing carbon fibre masts since at least 1994, and this was a topic of animated discussion at the competitors hearing and the secretaries meeting at the 2002 FD World Championships in Tavira. The case for and against was presented in Bulletin 146 (January 2001) “Carbon Spars 2000”, and that for adoption “Millennium Mast” by John Best, who had been sailing with a carbon mast obtained from Ken Brackwell of SuperSpars. However, at that time only a minority of the class was in favor of experimenting with carbon masts. Tony Lyall has since been sailing with a carbon Proctor Selden FD mast and enthusiastically recommends it. During the competitors hearing in Tavira Frank Havik suggested it was time for carbon masts to be allowed and this led to a discussion in which John Best (GBR 382) and Tony Lyall (GBR 385) presented the case for adoption, while Hans Peter Schwarz (GER 87) was co opted to present the case against, and I moderated the discussion. A number of factors were brought forward on both sides and will be presented below. It was suggested that the cost of carbon masts is slowly coming down while that of aluminum spars will eventually rise, although actual 2002 costs remained to be ascertained (and did not confirm this assumption).

The question was therefore put that it is not so much “if” the FD should allow carbon masts, but “when” should we allow carbon spars? The technical questions regarding the strength, quality control and effect on performance can probably be definitively answered by sailing trials. However, the effect of such a change on overall membership of the class, on participation and growth, are more difficult to gauge and requires feedback which I hope we will get via the internet. It would appear that class opinion, as expressed in Tavira, is now changing. A straw vote at the competitors hearing had 35 in favor vs. 24 against allowing carbon masts by 2004.

A number of classes such as the International 14 and many of the new manufacturer’s classes such as the 49er are using carbon spars and more and more dinghy classes are adopting them, most recently the Contender. The 505 class has a committee making recommendations to the class, which will be voted on at their AGM in Freemantle at the end of 2002. The manufacturing and quality control issues of the past have been essentially mastered. The almost exclusive use of carbon masts by high performance offshore yachts would confirm this conclusion. There have been some spectacular failures with carbon masts on large oceangoing multi hulls. These were due to rigging failures and the use of very high tensile carbon, which made the rigs susceptible to the high shock loads when burying a bow.

**Current Situation**

The current class rule 112 “Expensive materials” allow carbon fibre as a reinforcing material in hulls, rudder, centerboards, booms and spinnaker poles, but not on masts (including spreaders) and sails. Although in the past many different types of mast were used, current FD sailors primarily use aluminum masts manufactured by SuperSpars, Proctor Selden and Goldspar (44%, 33% and 23% respectively in Tavira 2002). The first two of these companies are in the UK, while Goldspar is in Australia. Thus FD sailors outside the UK and Australia have to import masts, and for many regions the transport, duty and dealer costs add prohibitively to the cost of a mast. Carbon tubes and masts are made by manufacturers throughout the world. SuperSpars actually imports their tubes from New Zealand. Furthermore, carbon masts are generally made in two sections making them much easier, and hence cheaper, to ship.

**Technical considerations**

In order to understand the ramifications of allowing carbon fibre masts it is important to outline some of the differences in physical properties of aluminum and carbon spars. The following is a short introduction to the technicalities.

**Weight and Center of Gravity**

**Table 1**

Mast Weight and CG above band 1

| Manufacturer | Aluminum | | Carbon Fibre | | |
|---|---|---|---|---|---|
| | Weight Rigged | CG | Weight Bare | Weight Rigged | CG |
| | kg | mm | kg | kg | mm |
| SuperSpars | 10.9 | 2975 | 4.9 | 8.8 | 2898 |
| Proctor Selden | 11.0 | | 4.5* | 9-10* | |
| Composite Spars & Tube CST | | | 4 - 5* | 6 - 7* | |

*Manufacturer’s estimate

What are the physical characteristics, which determine the performance of a mast? The weight and its distribution are clearly important. The weight, and how high it is, adversely affects the righting moment when heeled, and also the pitching response in waves. Thus in order to ensure masts of adequate strength, FD rule 58 specifies a minimum rigged weight of 11 kg and that the center of gravity (CG) be shall be more than 2500 mm above band 1 (the deck). These restrictions are equivalent to a minimum tip weight as used by some other classes. Although tapering of the mast tip is primarily done to produce desired bend characteristics and reduce windage, it also reduces weight aloft and hence together with light masthead fittings and spreaders reduce the height of the mast CG. The mass moments of inertia of the mast about the pitch and roll axes of the boat also affect the sailing qualities. However, as it is difficult to significantly change the moment of inertia without affecting other properties of the mast, and because it is difficult to measure, the mast moment of inertia is generally not controlled by class rules.

Present aluminum FD masts can be built weighing less than the 11 kg, however, their CGs are well above the minimum height. Carbon spars of similar strength and bend characteristics can be built with a weight which is half that of an aluminum spar, however, by the time one adds the spreaders, gooseneck, and shrouds etc. the weight is about 8.5 kg, a saving of only about 2.5 kg. However, Clive Watts of CST suggests it could be much lighter than this, they did a 7.5 m 12 skiff rig which was 3.2 kg bare and 4.5 kg rigged. Tim Willets (a well known builder of carbon International 14 and Finn masts) suggests that 6 kg is probably somewhat too low for an FD mast, as such low weights are achieved with large diameter low wall thickness sections fabricated with lower resin content, which can be unreliable. He suggests a minimum around 7 – 7.5 kg.

The height of the CG of the carbon masts is about the same as that for present aluminum FD masts, see table 1, and neither are anywhere near the minimum of 2500 mm above band 1. Despite this, Tim Willets suggested that the major stress points on a dinghy mast are at the vang, gooseneck and mast partners so this area should be well reinforced. A high CG actually leads to a need to save weight low down and can lead to unnecessary failures in these high load areas. From a safety point of view, a low mast CG is a definite advantage. There would therefore seem to be no reason to change our present minimum CG height.

The breaking strengths of modern high tech lines are comparable to those of wire, thus the rigged weight of either type of mast can be further reduced by using spectra (or other modern high tech line) for the trapeze wires as is common in other classes (Hideo used spectra as the luff wire for his Genoa in Tavira). Many competitors are using Spectra (or other modern high tech aramid line) for the under deck part of the forestay which is technically illegal (Rule 62) but the FD rule may be changed in 2004 to allow such spectra forestays. PBO fibre is the latest rage in the International 14; they can save 1.1 kg (from 1.5 kg to 400 grams rigging weight). The use of fibre for trapezes instead of wire is an added safety as it can be more easily cut in emergencies.

**Table 2**

Breaking strength of SS wire and Herzog Lightning line

| | Dia. (mm) | Strength (kg) | Dia. (mm) | Strength (kg) | Stretch at 30% load |
|---|---|---|---|---|---|
| 7 x 7 SS wire | 2.5 | 510 | 3.0 | 900 | 0.9% |
| Lightning Line | 2.5 | 635 | 3.0 | 950 | 1.2% |

While on the subject of the weight of the rig one can already reduce it by replacing the aluminum boom and spinnaker pole by carbon spars. The present

FD rules do not control the weight of these spars and as there is no all up sailing weight in the FD this is a free weight reduction. However, few sailors are taking advantage of this, while resisting the addition of even smallest correctors to their hulls! One of the reasons for this may be the high cost of carbon booms with sail tracks. A number of sailors have suggested that the FD allow loose footed mainsails, thus allowing the use of a simple tube as a carbon boom. This will be presented for discussion at the ECs in Como, July 2003.

**Bend Characteristics**

The static bend characteristics of a mast are also vitally important to its performance in a variety of wind conditions and with varying crew weights. For a homogeneous material such as aluminum alloy, the static bend characteristics of a tube are determined by the Young's modulus (i.e. elasticity) and the areal moment of inertia of the tube cross section. The product of the two values is called Flexural Rigidity. It is more difficult to bend a large diameter thin walled tube (Proctor F) than a thick walled small diameter tube (Old DeHavilland masts) of the same weight. The thinner one is, however, more prone to buckling failure. As soon as one gets away from a circular cross section one has to separately consider the fore and aft bend and the athwartships bend. This is especially true of the unsupported mast tip with its varying cross section (recall the Elvstom masts with their flat top sections which fell off sideways). The tips of some aluminum masts are tapered by cutting away part of the tube and then bending it closed and welding. Unfortunately, unless the correct heat treatment is used, the welding can change the temper of the alloy, i.e. its yield stress or elastic limit. There are also cross terms in the bending, i.e. the bending can induce a twisting of the section.

Another property of the mast material, which affects its dynamic response, is the internal damping or hysteresis. If you clamp a hacksaw blade at one end and displace the free end, it will oscillate back and forth (similar to a tuning fork). The frequency of the oscillation depends on the density, much less for carbon, and the Young's modulus. However, even in a vacuum, the oscillation will eventually die out because the energy is eventually transformed into heat within the material. This damping or conversion of the energy into heat occurs at different rates in different materials, i.e. the oscillation of a fiberglass sail batten will not last as long as those of a steel hacksaw blade. The recovery of the mast tip after a gust will be different for aluminum and a carbon fibre mast both because the oscillation frequency and the damping are different, even if they have the same static bend characteristics. This, together with the reduced weight, contributes to the different sailing characteristics of carbon and aluminum masts.

Carbon fibre however is a quite different material to aluminum alloy and is neither isotropic nor homogeneous. The strength of the carbon filaments (and there are different grades, some of the high performance types being very expensive) is in tension. This is true in the sense that the carbon filaments act like a rope, but if held rigid by the matrix then it is good in compression. Aramid (Kevlar, Twaron, and Technora) on the other hand is good in tension but one fifth the strength in compression. Glass fibre and Carbon fibre are the truly good composite reinforcing fibres, as when held rigid by a matrix the tensile and compressive strengths are both good. The fibres are thus embedded in epoxy resin to hold them in place. The performance of the resulting material depends on how straight, parallel the carbon fibres are, and the ability to support compression loads depends on the bond between the epoxy and the carbon, with any voids seriously degrading performance. Hence, most manufacturers use prepreg carbon filament, i.e. carbon filament that has been coated with resin to ensure uniform wetting. Clearly any cutting of the carbon fibres, such as at a hole, weakens the material. It is also clear that the properties of the material in a direction along the carbon filaments are quite different to those at right angles to this direction, where resin properties dominate.

This allows great variety in the engineering of masts made of carbon fibre. SuperSpars masts are fabricated from cylindrical carbon fibre tube with the carbon filaments primarily running parallel to the axis of the tube. The bend characteristics are thus uniform along the tube, the same fore and aft and athwartships, and determined by the inside and outside diameters of the tube. In contrast, Proctor Selden and Composite Spars and Tube use a winding machine to wind the carbon filaments onto a male mandrel, which can be of any cross section the designer chooses. Furthermore, the angle that the filaments make with the axis of the mast can be widely varied and can change along the length of the mast, thus changing the bend characteristics. This allows the bend characteristics to be tailored to the luff curve of the sail, or the crew weight. A third technique for mast making is to lay the carbon fibres into two female half molds. The two halves are then glued together. This allows masts of an aerodynamic shape, which can vary along the mast, and including a sail track, to be made. The disadvantages are that it is not easy to get the carbon fibres straight and that the two halves have to be joined along the length of the mast.

It should be born in mind that the FD mast is supported by the upper shrouds and spreaders as well as the lower shrouds and mast partners. The tuning of these stays to a large extent determines how that part of the mast which is below the hounds will bend. A stayed mast is therefore very different to a free standing mast, such as that in the Finn and Europe dinghies. In their case, the final bend characteristics are essentially determined during manufacture. Furthermore, these classes use rotating masts (forbidden in the FD, rule 57) so they are a quite different technological problem. The Finn and Europe class experience, which in any case has been during the period of initial development of this technology, is therefore not necessarily a good indicator for FD masts.

The addition of extra material in high stress areas such as the spreaders and the gooseneck etc. mean that the overall carbon mast section can be made lighter in comparison to a uniform section aluminum mast. Furthermore, by bonding additional material, or shaving it off, the bend characteristics can be fine tuned, rather as one did in the days of wooden masts. For example, many carbon dinghy masts are made in two sections with the sleeve area reinforced. The masts are only assembled after delivery, and can in fact be left unglued. In principle, this could allow one to change top sections to suit the wind conditions, only replace the top section if it breaks and will make for much easier trans-continental shipping.

One other technical consideration is that carbon fibre is electrically conductive as compared to other composites and this together with the differing thermal expansion enhances the corrosion of aluminum fittings in contact with carbon fibre. Thus fittings for carbon masts have to be carefully chosen, and mast manufacturers have developed custom plastic fittings for this purpose. The size and type of drills for making holes in carbon fibre also have to be carefully chosen and the edges of holes sealed. A new type of pop rivet has been developed to reduce the point loads and these should be used for mounting fittings. Therefore amateur construction, although feasible, is only to be undertaken by those who use the correct materials and techniques. Some mast manufacturers are unwilling to supply mast kits while others see no problem.

An important point is to be conservative and just make thicker walls. The class should set a minimum mast weight and diameter and then the fibre angle can be tuned to get the stiffness you need. You can make a mast that will never break, as there is no corrosion on the tubes and the fatigue resistance of carbon is like timber (also a composite) i.e. 10,000 times better than aluminum. They will last forever and not change from one year to the next. This leads to less cost and sail makers find is easier to build sails to a known mast bend. Composite Spars and Tube have made over 150 International 14 spars and tested many in the early years (for 15 in a row and the static bend test deflection was within 1-2%). Filament winding together with exacting manufacturing tolerances ensures exact replicas.

**Suggested FD Mast Rule changes**

The current FD rules (rules 57-64) specify the mast weight and dimensions, and are appropriate for aluminum masts. A large part of the advantages of lighter carbon masts would be negated under the present rules and so the FD class should reduce the minimum mast weight when carbon masts are permitted. The Finn class decided not to reduce the minimum mast weight and thus essentially all carbon Finn masts carry lead correctors (which now have to be visible). If we do not reduce the minimum mast weight then we may get masts filled with epoxy loaded with lead shot or other counterproductive devices. It remains to be seen at what the minimum weight a strong carbon FD mast can be built. However, based on the present carbon masts the minimum weight could be reduced to 8.0 kg or less (rule 58). Composite Spars and Tube have built a 9m 12 skiff no1 rig at 7 kg rigged and suggests that a FD mast would weigh 7 kg rigged. In order to allow 11 kg aluminum masts to remain competitive, a temporary transition rule requiring carbon masts to carry correctors at the spreaders could be written, so that it is invoked by the Notice of Race. Eventually, when the majority of the class has switched to carbon masts these correctors could be removed and such a rule no longer be invoked.

One of the reasons that the Finn carbon masts became so expensive is that they have rotating masts and allow a large fore and aft dimension. This led to expensive development of wing masts. Rotating masts are not allowed in the

FD (rule57) and to further discourage experimentation in this direction the maximum dimension of 100 mm fore and aft (rule 60) could be reduced. Present aluminum FD masts (and both present FD carbon masts) are all well within this limitation (Goldspar 62.6 mm dia, Proctor 57 by 72 mm) which could therefore be reduced to say 80 mm. Another alternative, which has been proposed by the OK dinghy class to avoid wing masts, is to is to restrict the fore/aft to side to side dimension to a ratio of less than or equal 1.7 (including the sail track) at any point along the length of the mast.

All present aluminum masts have CGs which are well above the minimum of 2500 mm from band 1 (rule 58). For example, the CG of a SuperSpars M5 is about 2975 mm above band 1 and that for their carbon spar was 2900 mm. In order to avoid experimentation with weight reduction of the tips and spreaders of carbon masts the minimum CG height could again be raised to say 2900 mm without affecting any present aluminum masts. This would also prevent competitors from just putting a lead plug into the heel of the mast to bring it up to weight.

A number of classes have restrictions on the bend characteristics of their masts, the FD only prescribes that the mast not be permanently bent (rule 57). In order to limit experimentation it would be possible to introduce a mast bend rule similar to the equipment rules of sailing (ERS) F.12.3. However, again I feel that this would not be in the spirit of a development class, and would therefore not recommend such an FD rule.

**Advantages of carbon masts**

What are the main advantages for the FD class if it allows carbon fibre masts?

- The mast will be significantly lighter and/or stronger. This reduces weight aloft and the moment of inertia, which improves performance in waves.
- The dynamic response of the carbon tip to gusts makes the boat easier to sail in heavy wind.
- This also allows a wider range of crew weight to be competitive. Helpful for lady crews.
- The reduced weight of the mast will make the boat much easier to right after a capsize and reduce the tendency to turtle.
- The reduced tendency to turtle will mean fewer breakages when sailing in shallow waters.
- In contrast to aluminum masts, which are generally not repairable, carbon masts can be repaired with negligible effect on performance, but repairs are probably better left to a local mast shop.
- Many carbon masts are made in two sections and joined at the hounds or lower spreader. This means that only the tip would need to be replaced if it is broken.
- A two section carbon mast could be used with different tip sections for different crew weight or wind conditions.
- A two section mast can be disassembled for initial transport, and even after use for transport in a container, as it is not necessary to glue the joint.

However, FDs require 40 foot containers, so there is no advantage when shipping masts together with boats.

- Carbon masts can be home built from tube stock by skilled amateurs or local yards, if commercial masts are not available.
- Stress points such as the hounds, gooseneck etc. can be locally strengthened so the overall weight of the mast can be reduced.
- With the reduced weight, it will be much easier to step and unstep the mast.
- Corrosion and fatigue resistance orders of magnitude better than Aluminum.
- Many suppliers in many different parts of the world

**Disadvantages of carbon masts**

Needles to say, there are also a number of considerations which might make it advantageous for the FD class to maintain the present ban on carbon masts.

- The cost of carbon mast is presently about twice that of aluminum FD mast and this is likely to remain so. The cost of carbon is mainly in the material and the high temperature autoclave required.
- The introduction of carbon FD masts will probably obsolete present aluminum masts, at least in some sailing conditions (but see transition strategy).
- The different tip bend characteristics may require mainsails with a different luff curve, however, initially manufacturers would match the present luff curve.
- The possibility of developing carbon masts with bend characteristics which can be varied along the length of the mast, may eventually lead to a new round of development of the mast-sail combination, thus possibly requiring the purchase of more that one new mast to remain competitive. This of course was the case in the early days of metal masts.
- The sailing technique with carbon masts differs from that for aluminum spars and will require a new learning period, at least in the middle of the fleet.
- The FD class has an, in my opinion undeserved, reputation for being expensive and carbon spars will only enhance this reputation. Mader, our main builder, believes that the extra cost will definitely reduce the number of new boats.
- Carbon spars require careful drilling with tungsten drill bits, sealing of the exposed edges and custom fittings and fasteners, or at least more care. Problems may arise if a sailor tries to use the old fittings from his aluminum mast and transfers them to a carbon tube.
- A characteristic of the powerful rig of the FD is that it is a boat in which the larger and heavier sailors have an advantage upwind in heavy winds, while being at a disadvantage downwind and in light airs. If the carbon spars allow lighter crews to be competitive upwind the heavy crew has no advantage at all and the FD would have to compete with many other classes for “average” size sailors. Presently we have a niche market for large sailors.

**Other considerations**

There are a number of other considerations, which need thought when the class makes a decision about carbon masts:

- The FD is a development class that has been at the forefront of development in dinghy sailing. Most modern dinghies now have carbon spars and in order to attract young sailors we need to be up to date. Introduction of modern carbon spars gives the impression of moving with the times.
- If the FD class is considering ways to upgrade the performance, in order to remain up to date, then perhaps other developments may be more cost effective. Fully battened mylar mainsails, such as that being tested by Hideo Tayama would be one possibility, although after seeing what happened to some of the 505 sails in Durban, I hesitate to suggest this.
- Loose footed main sails. A number of FD sailors have asked for this as the cost of a carbon boom is significantly increased when a sail track is required. A possible rule change will be presented at the ECs in Como, July 2003 for a class vote.
- The International 14 class now uses essentially only carbon masts thus suggesting that aluminum masts are no longer competitive in that class.
- The Fireball class has decided against carbon masts for the time being and the 505 have established a committee to make a recommendation to their class AGM in Freemantle, December 2002. Composite Spars and Tube have just finished the mandrel and are ready to make FD spars off the same mandrel.
- Carbon masts either have a significant advantage or they do not. If they are better, then everyone will eventually need to invest in a carbon rig, and that is expensive. Alternatively, if carbon and aluminum masts have similar performance then there is really no advantage to adopting carbon masts. This is somewhat of a catch 22 situation. Carbon is quicker and cost effective if you think of longevity, this is a critical point. Yes sailors have to pay up front, but really not much more than they spend on sails. Once you have the carbon mast, it doesn't need changing for years.
- The FD, with it's powerful Genoa, and small keel to deck partner dimension requires a stiffer mast than most other sailing dinghies and thus the advantages of carbon spars may be less pronounced than in other classes
- Carbon masts can be tailored to closely reproduce the bend characteristics of present aluminum masts, thus existing mainsails should still be fast with a carbon mast. However, the ability to fine tune the bend characteristics may in the future lead to the development of new mast-sail combinations, which are faster. This of course is still possible with aluminum masts, however, at present there seems to be little development effort in this direction.
- If the FD class is to eventually allow carbon masts then it should be done as soon as possible, so that sailors who are considering a new mast now, can avoid buying masts which may become obsolescent.
- Carbon spars are sensitive to UV degradation and therefore require an anti UV coating and more care, however, experience in other classes indicate that this is not a significant problem. The prepreg carbon tow used by Proctor Selden has an UV inhibitor so needs no further protection. This is a long term

effect and really only an aesthetic consideration (12 skiff guys haven't clear coated masts for years).

- The quality control of carbon mast production has, in the past, left something to be desired. However, the manufacturing techniques have now significantly improved and this is no longer an issue. The experience building carbon masts for the International 14, Merlin Rocket, Contender, Musto Skiff and many other dinghy classes means that mast manufacturers have invested in the equipment required to produce carbon masts of consistent quality. In this regard, the 505 class was experimenting with carbon masts in the late 1970s, so this technology is not exactly new. In 1982, the 505 class deemed carbon masts too expensive and banned them. They are currently considering lifting this ban.
- Companies such as Composite Spars and Tube in Australia produce masts for many skiffs and the International 14. They are developing a mast for the 505 and would be very interested in producing one for the FD.
- Carbon rigs are essentially universal in the sailboards. Their rigs have been continuously developed and are state of the art. Some of their experience can be applied to dinghy mast production.
- Although allowed, few FD sailors have adopted carbon booms or spinnaker poles despite their free weight saving, and greater strength.
- For aluminum masts, the cost is in the labor, as the material costs are only a small fraction of the total. For carbon masts, the material costs are significant and likely to remain so. The cost of a carbon mast is therefore unlikely to come down significantly in the near future.
- A number of modern manufacturers classes have masts with aluminum bottom sections and carbon tips. The mast manufacturers consulted suggested that this option would be as expensive as a full carbon mast and not have the benefits. It might be possible to fit a carbon tip to an existing aluminum mast and get the gust response characteristics. However, the sleeve joint would have to be custom engineered and so may negate any cost savings. Corrosion is also a major issue, as aluminum and carbon act like a battery.
- In order to remain attractive the FD needs to be able to compete in speed with other dasses in open regattas. The FD has the reputation of being the fastest two man dinghy and must therefore continue to develop in order to maintain this reputation.
- When a FD is sailed upright on flat water, i.e. on lakes, there will be little or no speed advantage to a carbon mast. Thus, aluminum masts will not immediately become obsolete.

**Cost**

On my return from Tavira I contacted both Ken Brackwell of SuperSpars, Chip Howarth of Proctor-Selden and Clive Watts of Composite Spars and Tubes, as well as a number of other carbon dinghy spar manufacturers. However, my Internet search was not exhaustive, and I am sure there are other manufacturers who would quote on carbon FD masts.

A SuperSpars M5 aluminum mast with fittings is £450 compared to a carbon FD mast at £880 and a set of rigging including lowers and low stretch shrouds is £115. A SuperSpars carbon boom is £200 plus £30 and £12 if the track and kicker strop respectively are fitted. A 38 mm OD carbon spi pole tube only is £67.50. All these prices are excluding VAT.

The Proctor Selden carbon mast is £800 plus tax, while the rig package including T wires is £150 plus tax. The 88 mm diameter carbon boom including track is £330 plus tax while the Proctor carbon spi pole including end fittings is £86 plus tax. The bare mast tube wound with all local strengthening is about £560 plus tax.

The SuperSpars and Proctor Selden masts are made in England while the Goldspar is produced in Australia. For FD sailors in other parts of the world the transportation costs and duties are a very significant part of the total cost. Carbon masts have a major advantage in this regard, as they are shipped in two sections and assembled locally. It is also possible that other manufacturers in New Zealand and the US, to name just two countries, would produce competitive masts so that competitive masts become available worldwide. It is also possible to “home build” carbon spars with the costs of materials and duties being much less than for a complete mast.

**Timeline**

It is now about a decade since the first carbon dinghy spars appeared in competition and the FD technical committee first studied their possible adoption by the FD class. Two members of the class have used carbon masts on their FDs and sailed in regattas at which they were given permission to do so. There is at very least an enthusiastic group of FD sailors who feel that the time has come for the FD class to allow carbon masts. In the interest of those FD sailors who are considering the purchase of a new mast in the near future any changes in the FD mast rules should be clarified as soon as possible.

However, even if the class made the decision to allow carbon spars now (December 2002) it would have to be ratified at the ISAF meeting in November 2003 and would only come into effect in March 2004, i.e. almost a year and a half from now. The deadline for submitting rule changes to ISAF for ratification is in September each year, so we have at least a whole sailing season to conduct further tests and to debate this issue. This also gives the executive time to decide on a mechanism for ascertaining the will of the class on this subject. National secretaries should make their members aware that this question will be debated at the European Championships in Italy in July 2003.

**Transition strategies**

In order to make a transition to carbon masts less traumatic and to allow FD sailors to continue to use aluminum masts, without suffering a real or imagined handicap, a number of alternative transition strategies suggest themselves.

The most obvious advantage of a carbon mast is the reduced weight (8.5 kg). In order to counteract this advantage the class could introduce an equipment limitation rule similar to rule 113, which can be invoked by the Notice of race, to the effect that carbon masts must carry corrector weights at the spreaders to bring them up to the present minimum weight of 11 kg. Carrying the correctors on the spreaders would maintain the CG at a height, which is comparable with the present aluminum masts (well above the minimum as specified in rule 58). These weights would be clearly visible, and although required for regattas, which invoke this rule, would be easily removable for regattas which do not invoke the rule. In time as more competitors sail with carbon masts this rule would become obsolete.

The primary drawback to carbon masts is their significantly larger cost. This could be reduced by making arrangements with the mast manufacturers to buy a bulk order of say 100 masts, and the suppliers have suggested they would be interested in such an arrangement. However, I do not think that the class organization should get involved in the commercial aspects of FD sailing and I do not see any other organization, which would be willing to make the investment.

Alternatively, the class could limit the supply of carbon masts to one or perhaps three suppliers for a transition period. This would give these mast manufacturers a monopoly for an initial period, so that they could achieve some economy of scale. Again, I feel that limiting the supply of masts is not commensurate with the philosophy of a development class. It would also increase the cost to FD sailors outside Europe who might otherwise have a local supplier or home build their masts.

It has been suggested that the class restrict the cross section to being circular plus a sail track. However, it can be seen above that this does not reduce the price (SuperSpars are circular while Proctor-Seldens are a custom cross section).

**Summary**

I hope that the above material will give FD sailors information on some of the points which need consideration when the class makes a decision on carbon masts. Modern carbon masts can be tailored to the class, and can either be much stronger and/or lighter than present aluminum masts, which have similar bend characteristics. They are significantly lighter and have a superior gust response. This makes them easier to handle by a wider variety of crews, but may require a change in sailing technique. Their reduced weight will make for much easier recovery from capsizes with fewer breakages from turtling. The fact that they can be left in two sections makes transportation much easier.

However, they are about twice as expensive as aluminum masts and are likely to remain so. The price difference for fully rigged masts will however, be somewhat less. For the FD, it is not clear that there will be a significant increase in performance. The class is fortunate to have two members who have experimented with carbon FD masts and further trials are planned in 2003. These two-boat trials should provide data on which the performance can be evaluated and it is hoped that a number of regattas will allow the use of carbon masts for evaluation.

The primary decision that the FD class has to make is however, in my opinion, not a technical one. Rather, the class has to evaluate the benefits and drawbacks of allowing carbon spars on the present and future class membership. Is this the time to go ahead? Alternatively, can we wait until the unlikely eventuality that the price of carbon masts comes down? Will the FD class attract more new members than it looses? Leonard Mader feels that the FD is seen as an expensive boat (he has offered an "economy model FD without some of the more exotic fittings) and feels that the extra cost of a carbon mast will definitely have a negative effect on class growth. I hope that this question can be aired on an Internet chat room so that all members of the class can have input.

I would like to acknowledge the help I have received from Chip Howarth of Proctor Selden and Ken Brackwell of SuperSpars who supplied their technical and cost data and explained many concepts to me. Clive Watts of Composite Spars and Tubes made many helpful suggestions, which have been incorporated, many thanks. Ali Mellor's 505 website appreciation of carbon spars was also a fruitful source of ideas. Last, but not least John Best, Tony Lyall and all the FD sailors with whom I have discussed carbon spars. Please e-mail any comments and opinions so that I can collect them before the European Championships in Como, July 2003.

**Some Carbon fibre Spar links**

Other classes:

ISAF site. www.sailing.org
505 class, www.int505.org/2001AGM-CarbonSparsIssue.htm
International 14. www.i14.org
OK Dinghy. www.okdia.de/building_carbon.htm
Finn. www.finnclass.org
Europe. www.europe.org

Carbon dinghy mast manufacturers:

Waterat Sailing Equipment. e-mail larry@waterat.com.
Built multiple carbon fiber 505 masts in 1981
Superspars, Ken Brackwell, www.superspars.com /carbontechnical.html
Proctor Seldén, Chip Howarth, www.seldenmast.co.uk
/Datasheets/Carbon.htm
Composite Spars & Tube, Clive Watts, www.compositespars.com
Composite Solutions Inc. www.csi-composites.com
Carbospars- www.carbospars.com
Carbon masts for Finn, racing and cruising
CompoTech, www.CompoTech.com Filament wound structures
Fibre Glast Developments Corp. www.fibreglast.com
- Fiberglass,Carbon Fiber material suppier.
C-Tech Ltd. www.c-tech.co.nz 14 foot Skiff masts - high-quality carbon fiber
and composite components for the marine industry
Sail Center (Marstrom). www.sailcenter.se
Applied Composite Technologies. www.composites.com.au
Chipstow carbon fibre and dinghy products. www.chipstow.co.uk
Composite Engineering Inc. www.vanduesenracingboats.com
Hall Spars, www.hallspar.com. The hall brothers are ex FD sailors

Do It Yourself Links:

Building Carbon Masts, from the Cherub Web Site.
www.sailingsource.com/cherub/masts.htm

Technical articles:

The carbon case by Phil Draper, Yachts and Yachting October 26 (2001) p.27-31.

Mast Crusader by Rob Andrews, Yachts and Yachting October 25 (2002).