WING MASTS

These fast, efficient performers represent a cost-effective alternative worth considering

Many sailboat builders, amateur and professional alike, are turning to composite wing masts where high strength, minimal overhead weight, and much-reduced drag are prerequisites.

Wing spars can be effectively fabricated in lengths as short as 25' and can be as tall as the 104' mast built for the 80' French catamaran Royale II. They have been rigged as free-standing prototypes on Gary Hoyt's Freedom 25 and as aftermarket additions on Hinterhoeller's Nonsuch 30. Multihull designer Dick Newick has used wing masts on many of his boats, including the Creative and Native series.

Further testifying to the effectiveness of these spars, a long line of trimaran designs such as Crowther Buccaneer 28s, 33s, and Twiggies; Southern Cross 34s; and Kantolas sail with wing masts. So do many popular production catamarans, including MacGregor 36s and Stiletto 27s. Gougeon Brothers put Stresform wing spars on three of its best-known trimarans: the speed-sailing record contender Slingshot and the cruiser/racers Ollie and Adagio. Eric Taberly's big ocean-racing tri Pen Duick IV was fitted out as a ketch, with two wing masts.

A non-rigid wing spar (the type we'll discuss here) looks rather like an airplane wing set vertically on a rotating joint fastened to the boat's deck. The mainsail is bent to the trailing edge of the spar, which is teardrop-shaped in section and becomes an integral part of the "plan form," or profile, of the rig. Typically, the mast portion of the rig represents between 5% and 15% of the total mainsail area.

by Ted Hugger
This 36' mast, for designer Eric Sponberg's Delft 25, is cylindrical in shape at its base, shifting to a conservative 2:1 ellipse between 6' and 16'. Note that the spar begins angling aft at the 6' height. Both features relate to the fact that this mast can be rotated to optimize performance while underway. The spar is built over a framework of ½" plywood "battenheads," spaced every 2' and linked by ¾" spruce "half-round" longitudinals and a vertical plywood web. Sheathing is ⅛" spruce veneer, overlaid with a carbon-fiber laminate.
Although certainly more costly than a mass-produced aluminum mast, a wood/epoxy or carbon-fiber composite wing spar can be less expensive to build than a one-off or limited-production aluminum spar of the same weight. Moreover, for a given length, the wing mast can be far lighter, potentially boosting efficiency and performance.

**Turn, Turn, Turn**

Because most composite wing masts are designed as rotating spars, the airflow in the mast-to-sail transition improves dramatically when the mast is rotated into the wind, resulting in less drag on the low-pressure side and in greater driving power.

Although the performance of a standard oval aluminum mast can be improved if it can be rotated, the structural complications of such a rig become almost overwhelming as both boat and mast increase in size. A conventional aluminum mast requires a great number of stays to keep it “in column” and to ensure proper load distribution; when that mast is set up to rotate, the alignment of fittings and stays becomes even more critical—and very difficult to achieve and maintain.

A typical aluminum mast of, say, 8” in diameter just doesn’t have the geometry to support itself. A wing mast designed for the same boat, however, is much larger in cross section—as much as 18” fore-and-aft—and, so, does a much better job of holding itself up. Imagine two different tubes, a 1” diameter round one with relatively thick side walls, and a 2” x 1” oval one of the same length and weight. The smaller tube flexes easily, while the larger, oval one resists bending. This tube’s geometry gives it a much greater load-bearing capacity.

Whereas the traditional spar requires a tangle of wire or rod rigging, and, in some cases, elaborate spreader systems, the stiffer wing mast is relatively free of such overhead weight and windage. Instead of a dozen wires, the wing mast may only require three stays.

The penalty for creating such a wing-mast rig in aluminum would be a huge and unacceptable addition in weight and mass. In short, a composite wing mast is simply an aerodynamically more efficient method of harnessing and controlling wind energy.

**The 100% Solution**

Roger Hatfield of Gold Coast Yachts (St. Croix, U.S. Virgin Islands) builds many of the excursion catamarans that have become so popular with the day-sailing crowd at many warm-water tourist destinations. Hatfield’s boats are big, ranging from 42’ to 65’ in length; his most successful design is a 53-footer, and seven boats of that design have been launched to date. His 16th catamaran has now been completed and has joined the charter trade. All of Gold Coast’s boats are set up with wing masts—and with good reason.

The day-charter trade has presented Hatfield with some very specific challenges in boat and rig design. Day in and day out, making two or three trips every 24 hours, Gold Coast vessels are put through their paces under a variety of conditions. They often have to sail short-handed. They must comfortably and safely carry a large group of both seasoned and green sailors.

The big cats have to do a lot of maneuvering in popular—and therefore crowded—anchorages throughout the islands. But, these boats routinely venture out into open water, as well.

Hatfield explains, “By their nature, our cats must have good performance, handle well, and offer simple operation. And, as with any heavily used commercial boat, the rig and its systems must have good long-term maintenance characteristics. If there had ever been any question about how well wing spars work in terms of handling ability, maneuverability, or serviceability,” Hatfield says flatly, “I would have gotten rid of them a long time ago.”

Hatfield contends that a wing mast, with its full shape and superior stall-avoidance characteristics, allows his...
boats to operate efficiently at a higher angle of attack, with much better tacking response. And by foregoing an aluminum spar, Hatfield has eliminated the usual spider web of expensive, drag-inducing, breakdown-prone wire rigging.

On a catamaran with a traditionally stayed rig requiring large headsails and a corresponding amount of headstay tension, proper sail set and trim become nearly impossible. "It's ridiculous to try to get headstay tension on a catamaran," Hatfield explains, "so we have to concentrate on the mainsail rather than the jib—and that's where the wing mast delivers. The jib can be very small, acting only as a balancing sail, while the main is the prime power source.

"A wing spar permits the designer to leave between 25% and 35% of the mast's length unsupported by wires, therefore allowing a much larger mainsail without requiring huge amounts of structural mass." There is an incredible reduction in the amount of turbulence generated aloft.

"The drag and turbulence created by wire is incredible," says Hatfield. "C.A. Marchaj, in Aero-Hydrodynamics of Sailing, states that a 1" diameter wire creates the same drag, resistance, and turbulence of a foil 10" thick and 50" long, if the foil is oriented into the wind."

A wing mast, particularly a free-standing spar, really opens up the possibilities of mainsail shape.

The Shape You're In
Designer Eric Sponberg (Newport, Rhode Island) agrees with Hatfield's conclusions. "A wing mast, particularly a free-standing spar, really opens up the possibilities of mainsail shape," Sponberg explains. "In a regularly stayed rig, you're bound to the triangle between the mast and the backstay. And that triangular shape is absolutely the worst possible plan form you could ever want in a lifting foil. This explains why we never see triangular keels or rudders.

"If you're sailing with a triangular-shaped mainsail, and you want to make it more efficient, you have to pull the head of the sail to windward, essentially twisting it in an unnatural direction. That optimizes lift but not drag. On the other hand, if you have more of a quadrilateral, or four-sided, sail plan, as in a gaff rig or an elliptically shaped rig, that unnatural twist is practically zero. Only a little bit of the sail's top will twist to leeward, which is the way it goes naturally. That rig—and shape—is much more efficient," Sponberg concludes.

A wing mast allows the designer to create an elliptical plan form by cutting the head of the sail with a high degree of roach, using full battens to maintain sail shape. The result is a much more efficient plan form, which has a very clean leading edge and needs minimal rigging to hold it up.

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Although wing spars can be found on both multihulls and monohulls, the rig pays greater dividends on a multihull because these designs are much less prone to heeling. Notes Sponberg, "As soon as a boat starts to heel, you lose efficiency and the ability to transfer power from the wind. At the same time, you are picking up a huge increase in drag.

"Multihulls stay relatively straight and flat, so the rig stays up straight; the result is very little drag. That's why, since 1980, we've seen so many wing spars on multihulls—they're really the ideal rig for that platform."

Sponberg cites what he feels is probably the ultimate wingmast rig in terms of sailing efficiency: the multi-component setup aboard one of the Stars and Stripes catamarans. In place of a traditional aluminum mast and a fabric sail, the boat carried a rigid wing, not unlike a vertically set airplane wing. It had three basic vertical elements. First, the leading-edge shape was a D-section spar, the primary structural component. The middle element, located behind the spar, offered a limited amount of independent rotating ability.

The trailing-edge component was the truly movable element of the rig. Built in eight different sections, stacked one atop the other, this part of the "sail" could be swung from side to side to ensure that no wind gusts would carry the rig away while the boat was not being used.

"Wing masts of much smaller section, with the mainsail attached to the trailing edge of the foil, are less efficient but far more versatile and practical than huge rigid wings.

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be motoring or motorsailing, and then the rig's reduced drag pays off in both performance and economy."

**Construction Considerations**

Because of his boats' mission, Hatfield isn't as concerned with weight as those who might be designing or building racing boats or other high-performance craft. Gold Coast catamarans, he says, more closely parallel cruising boats than raceboats, in terms of their performance capabilities and scantlings. Safety and ease of operation must be built into them.

Hatfield, therefore, believes in simple wing-mast scantlings. He stripsplanks his spars with Douglas-fir and sheathes the masts, inside and out, with 10-oz fiberglass cloth set in epoxy. The spar for a typical 53-footer measures 12" thick and 24" fore-and-aft. The 61'-tall mast is stepped on the cabin, rising 70' above the water. All-up weight for the rig is about 1,000 lbs. The bare tube tips the scales at about 10 lbs per foot.

Some wing-mast proponents might find this weight excessive, in spite of Hatfield's argument that the Gold Coasts are workboats (the 53' cat weighs in at 20,000 lbs). There might be some difference of opinion, too, about his choice of foil shape.

Hatfield's wing masts have a very round leading edge and a foil with a 2:1 chord-to-width ratio (the relationship between the fore-and-aft dimension of the mast and its width). By contrast, many wing masts—like those designed by Michigan's Gougeon Brothers—are often 3:1 sections.

"The rounder shape," explains Hatfield, "is important in our boats. It tends to be more forgiving of rotational trim in medium wind conditions and is less likely to develop excessive lift at lower wind velocities. But, more important, it is unlikely to develop uncontrollable lift in bare-pole situations, such as the conditions experienced by our boats during Hurricane Hugo."

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That storm, which devastated the Virgin Islands, taught Hatfield some valuable lessons about wing masts. Two big Gold Coast cats with 2:1-ratio wing spars were lying at anchor directly in Hugo's cross hairs. Winds of 140 knots with gusts to 200 knots attacked the boats—first from one quarter and then, suddenly, from the other—as the storm roared overhead.

"The boats stood up to it," Hatfield reports. "Unlike many conventionally rigged boats, which suffered severe rig and structural damage, the wing-spar cats rode out the storm in good shape."

**On the Safe Side**

Like Hatfield, Sponberg tends to be conservative in his selection of foil sections, usually not exceeding a 2:1 chord-to-width ratio. He says there is a danger in going too narrow, namely that the narrower the wing section, the easier it will be to stall the rig (i.e., reach the point at which the rig loses lift and the ability to translate wind energy into boat movement).

He says that since stalling is largely a function of the angle of attack, the problem becomes more critical on a monohull. Such a boat tends to rock from side to side, so its rig's angle of attack is constantly changing. Sponberg contends that a forgiving, well-rounded nose on the leading edge of a wing mast will help reduce the tendency of the rig to stall.

There are also construction considerations in selecting the chord-to-width ratio of a wing spar. Sponberg recalls a monohull mast he designed several years ago for Goetz Marine Technology (Bristol, Rhode Island). "It had a 4:1 ratio, and we used an airfoil with good lift characteristics at very low wind speeds. Because of the complexity of that shape, we had to plot out sections every 2' so the builder could construct full-size templates. That required offsets for every section."

By contrast, the spar for Sponberg's Delft 25 is a study in simplicity. Engineering the shape of its 2:1 elliptical sections, he says, was much easier than plotting out the more complex shape of airfoil sections (see illustration, page 9). Although this spar is rigid with a headstay and running backstays, Sponberg says he designed in enough strength so that it can stand alone. The stays are needed only to establish and maintain the best foresail shape.

Working from section patterns that are drawn full size on the plans, the builder of a Delft 25 mast constructs a wooden, crate-like structure over elliptical stations of 1⁄8" plywood located every 2' along the length of the mast. Leading and trailing edges are fabricated of ¼" spruce stock. The crate is then overlaid with ¼" spruce veneer, followed by a laminate schedule of carbon fiber and resin.

**Tortured-Plywood Construction**

Gougeon Brothers, Inc., whose wingmast designs have been installed on hundreds of yachts, employs a different construction system, which results in what the company has dubbed its Stresform spar.

The Gougeon technique relies on stressed, or "tortured" plywood as the primary structural element in the spar, with carbon fiber providing only localized reinforcement. In contrast, Sponberg's masts depend solely on their carbon-fiber laminate for structural performance. The Stresform alternative, says Gougeon's technical advisor, J.R. Watson, is particularly suitable for one-off and amateur construction, due to its relative simplicity.

"With a minimal investment in mate-
First, epoxy-coated plywood skins are bonded to a spruce "nose" stringer with thickened epoxy. Next comes a lightweight plywood shear web with carbon-reinforced spruce stringers that run the full length of the wing's interior, providing lateral support. Other internal components, such as the mast-step and internal halyard systems, are also installed at this point.

Finally, the mast is "folded," and the trailing edges of the plywood are glued to a spruce "tail" stringer and aluminum sail track. Once the spar is installed in the boat, additional column stiffness is provided by single diamond stays, rigged from the hounds, routed over a single spreader, and anchored at a point near the base of the mast.

Watson says that Gougeon’s Stresform construction system is one of the reasons the company has settled on a chord-to-width ratio of 3:1 in its wing spars. Due to the folding process, builders using the tortured-plywood technique, he says, can achieve a near-perfect 3:1 section without extensive molds or framework.

But, Watson clearly disagrees with 2:1 proponent Eric Sponberg in citing performance advantages as another reason for the larger ratio. "The 3:1 spar can be longer for a given stiffness, with much better lateral performance," claims Watson. "A 2:1 wing spar will exhibit the problems associated with any rig of greater surface area, including a leading edge that isn’t as clean."

"We’re using geometry to make the mast stiff," Watson explains. "By building at 2:1, you give up critical fore-and-aft geometry at the expense of greater weight to achieve the same stiffness."

The 3:1 configuration, Watson says, results in a much cleaner, more powerful foil section to drive the boat.

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Dollars and Sense

Most designers agree that it's tough to make a simple cost comparison between conventional rigs and those based on wing masts. Sponberg, however, finds a useful example in the Whistler 32, a Chuck Paine design built by Able Custom Yachts (Trenton, Maine). The boat is offered in two configurations: a sloop with a conventional aluminum mast and rig, or a cat-ketch with two free-standing, carbon-fiber spars.

When Sponberg studied this boat, the weight of the completed rigs, as well as their installed costs, were about the same. Based on this fact and other data, he believes that for boats under 35', a conventional aluminum rig is probably lower in weight and cost than a free-standing composite rig. For vessels in the 35-40' range, Sponberg concludes that the weight and cost of the two alternatives are approximately the same. And for boats of more than 40', the carbon-fiber, free-standing rig will be lighter and less expensive.

Sponberg feels that the similarities between free-standing composite spars and composite wing masts then allow him to draw valid conclusions about relative costs: "A wing mast might be slightly more expensive to build than its free-standing, carbon-fiber counterpart, but it would not be significantly so. I'd guess that up to 45' or 50', the composite wing mast and conventional aluminum spar would cost about the same. On boats of more than 50', the wing-mast rig would be cheaper."

Rob Monroe, general manager at Gougeon Brothers, feels that wing spars—particularly those of wood-composite construction—are competitive in price and have a definite place in today's production marketplace. "Unless you're building a significant number of identical masts and can amortize the cost over many rigs," says Monroe, "the expense involved in manufacturing custom aluminum spars is prohibitive. Because the fold-up procedure in our Stresform masts is a self-forming process, you don't need the costly tooling required in aluminum-spar construction."

Monroe points out that the materials used in a typical wood-composite mast—plywood, spuce, carbon fiber, unidirectional fabric, and room-temperature-cure epoxy—are relatively inexpensive. This, he argues, makes the technology a viable alternative for today's cost-conscious, performance-minded sailboat builders.

Gold Coast's Roger Hatfield sums up the wing-mast decision: "I build catamarans because I believe in them, and I use wing masts because I believe in them. But ultimately, and most importantly, I put wing masts on my boats because my customers believe in them."

About the author: An avid sailor and amateur boatbuilder, Ted Hugger is marketing director for WoodenBoat and Professional BoatBuilder.