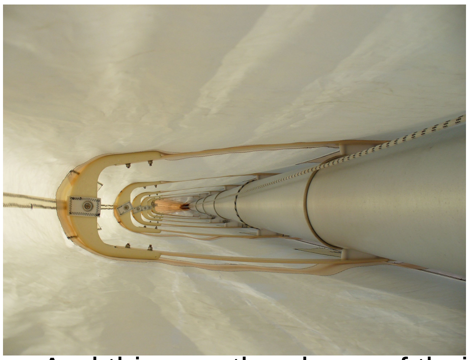
Tystie's rig update, December 2009 to January 2010

By the time *Tystie* arrived in New Zealand, she had sailed more than 40,000 miles with the soft wingsail ketch rig that I had built in early 2005. It had proved itself to be a sound, seaworthy rig, with less tendency to chafe than the single junk sail previously set, and with fewer operational problems. The ketch format was better for fast, rugged cruising, with its larger driving sail forward, and its smaller "trimming" sail aft (*Tystie*, as a consequence of her shoal draft hull shape, develops weather helm early, and the first reef is always in the mizzen). The windward performance was as good as, or better than the single fan-shaped junk sail (where a junk-rigged ketch would undoubtedly have been worse). Deep reefing, in strong to gale force winds, was easier and more effective than with the single sail.

But I had been aware for a long time of these faults:

- I did not put in as much camber as I should have done.
- The luff did not have enough internal support, and did not keep its shape, especially when the sail was twisted, or the boat was pitching.
- The sail above the top batten never contributed much to windward performance, due to its poor shape.
- The battens were disinclined to articulate freely, due to the friction generated in their housings in the aft ends of the wishbones (even though I had used HDPE linings). To get reliable articulation when tacking, I had to put in limit stops in the top two wishbones, to 5° and 10° rather than the 15° of the lower battens, with a consequent reduction in drive in the head of the sail.
- The sail area needed to be increased; and with that increase added forward, to reduce weather helm.

This was the shape of the original forward end of the original wishbones:



And this was the shape of their aft ends:

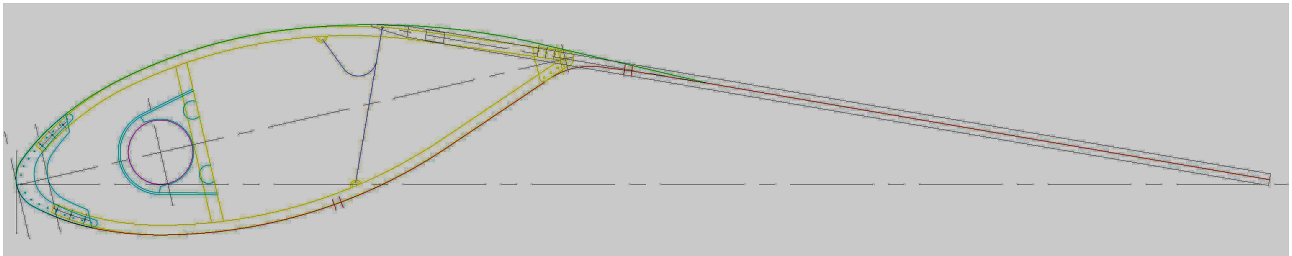
The sides were of 45 x 5 pultruded GRP, bound with glass cloth; the batten box was filament-wound around these, using a former and a mould; the bridge, bearing against the mast, was cut from 12 thick HDPE sheet; and the nose was a GRP moulding.

As you can see, the sides of the wishbones were straight and parallel – I had hoped that the lee side would be drawn out into shape by the low air pressure, and that the windward side would remain flat, not convex. This was completely erroneous thinking, both in terms of aerodynamics and of practicalities. The lee side would not take a stable curve, and the windward side should not be completely flat.

As we sailed down America's west coast and on across the Pacific, I put a lot of time into studying aerodynamics, and into thinking about what sort of foil section and batten construction would :

- give improved windward performance
- retain the essentially docile, easily handled, easily reefed and furled nature of the junk rig
- be lighter in weight than the original GRP construction
- be within my ability to build, with only basic home workshop facilities likely to be available
- be affordable.

Although I could dream up a number of different configurations, most of them would not comply with all of these points on the wish-list. In the end, it seemed that there was no sensible alternative to a version of the design method described by Thomas Speers, in his paper on hard wing mast/soft sail design. In essence, this takes the upper (lee) side of a foil of suitable characteristics; a line is drawn from the leading edge to a point on the curve corresponding to the aft face of a hard wing-mast, or the hinge of a wishbone in a soft wingsail; and the forward part of the curve is mirrored about this line to describe the windward face of the mast, or sail. Speers uses the old, well known, Clark Y foil as his basis, and indeed this would be quite suitable for a wing-mast for a fast multihull; but I felt that a thicker, more cambered foil would be better for driving a slower, heavier cruising yacht. I settled on Wortmann fx77w153 – the after half of its upper surface is a straight line, which goes well with junk-like straight, stiff battens, and all the curvature is in the forward half, which means that the forces are developed close to the mast, decreasing weather helm and sheet loads. A possible alternative would have been UI1720, developed for use on hang-gliders and microlights, but this one has an even longer straight section, and the hinge point is pushed unacceptably far forward. Here is a section through the mizzen sail, using fx77w153:

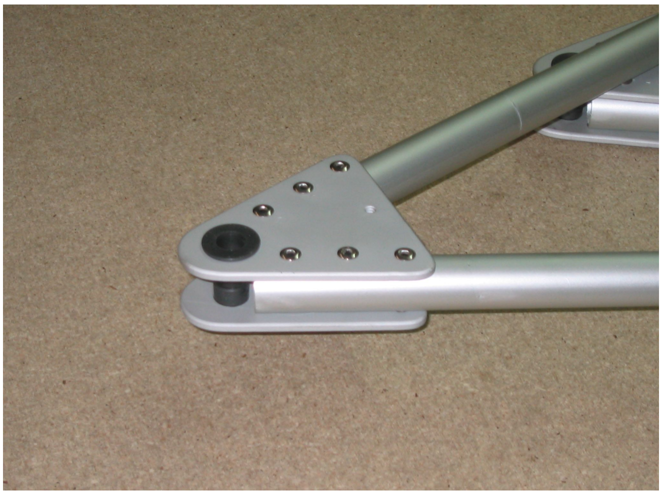


As I approached Auckland, Paul Thompson got in touch with me, and offered the use of his workshop, well situated in an area with all the materials, services and facilities likely to be required close at hand. This pushed me on a stage, from “what I'll do to improve my rig if I ever get the chance”, to “Now's the time, I'll never get a better chance”.

A look at the cost of sailcloth in New Zealand convinced me that I had to re-furbish my existing sails. They are stretched in places, the cloth is shiny where minor rubbing has occurred, and patched in way of the halyards and flag halyards, but they were basically sound, with apparently no UV induced weakening in cloth or thread. I determined to alter the mizzen only as required to suit new battens, and in the mainsail, to take out the two narrow cloths either side of the luff, and to replace them with cloths of 50% more width (adding the required extra area), otherwise altering it only as required to suit new battens.

So as to accommodate the extra mainsail width, the mainmast is now at 18% of the chord, most of the area having been added to the luff; and the mizzen has moved aft, so that the mizzen mast is now at 11% of the chord. Previously, both masts were at 15% of the respective chords; that would still be my preferred position if I were designing a new rig.

Some elementary weight calculations showed that I could make significant reductions if I used aluminium alloy for the wishbones and battens. I have used ø25 x 1.42 tube for the wishbones sides, 32 x 25 x 3 channel for the wishbone bridges, ø32 x 1.42 tube for the mizzen battens and ø38 x 1.42 tube for the main battens. At the aft ends of the wishbones triangular plates of 5 thick aluminium alloy sheet join the tubes and carry two off-the-shelf plastic bearings; a stainless steel welded fitting is riveted to the batten and engages with this bearing. I chose riveted construction rather than welded, so that I can easily carry a kit of spare wishbone parts aboard, and replace any damaged components. Here is one of the mizzen wishbones, with its nose of 10 thick black HDPE sheet, and its mast bearing, saved from the previous wishbones, of 12 thick white HDPE sheet; and a closeup of the hinge plates:

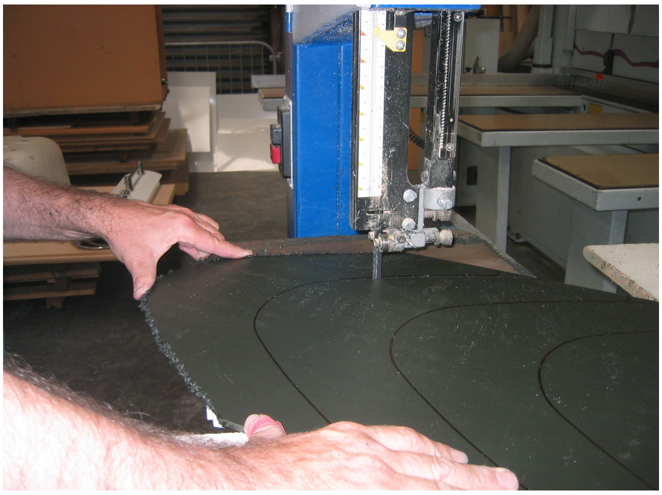


[An alternative for the wishbone bridges would have been 32 x 32 x 3 square tube, so that having notched the ends for the round wishbone tubes (by hole-sawing ø25 and then hacksawing from the ends), both top and bottom faces of the bridge would have been engaged with the wishbone, placing less reliance on the rivets.]

Here is the bending method for the wishbone sides. A former is made from MDF, and body weight is enough to bend ø25 tube. A great deal of trial and error is needed to establish the radii of the former; the tube must be over-bent and then springs back to the required shape. But then each tube can be bent in a matter of seconds.

Checking the shape against a full-size template:

Band-sawing the noses:



Using a template to router the rough-cut noses to shape and round off their edges:

(this is Paul machining noses for his own rig – after seeing what my rig consisted of, he abandoned his plan for a cambered panel junk rig, and is making wingsails like mine, but in a schooner configuration)

Here is the hinge arrangement, on the stack of wishbones assembled on to the mizzen mast (with the partly-rigged mainsail in the background). There is a washer either side of

the bearing, and a ø4 rollpin through the ø12.7 stainless steel tube which forms the hinge. Later, the batten tube will be slid into the larger stainless steel tube, with some mylar film wrapped around it to isolate it, and after adjusting the tension of the sailcloth, two rivets will be put in from below.

Here is the method for limiting the articulation of the battens. A wedge-shaped batten forward end, of plastic bar, has a ø4 Dyneema cord secured to its end, and this cord is secured around the wishbone tube, with a small lacing eye to position it. The photo was taken with one reef down. On the reefed batten, above the lowest batten, it can be seen that the Dyneema cords pass through a ring, to which is secured the downhaul. I had thought that it might be necessary to centre the battens during tacking in light airs, and this system will do that. But in fact, the hinge as pictured above has so little friction that articulation is very smooth and easy. The rings have now been taken off and the downhauls lead directly to the wishbone bridges:

Going back to my list of the faults in the previous rig – number 2 was the lack of sufficient support for the luff area of the sail. The wishbones alone, at 1200 spacing, are not enough. A study of the large number of cambered foils meant to develop lift shows that they have several things in common:

- An upper surface that is convex throughout its length (or sometimes straight in its after part, as in my chosen foil)
- A leading edge that is rounded, with a radius usually about 2% of the chord
- A lower surface that is convex for about the first 10% of the chord, before turning straight or concave.

It is this last feature which is often overlooked, or misunderstood, and yet it is as important as the other two. Looking at the airflow around a foil by means of a computer simulator (Designfoil, or the educational one that NASA has on its website) or by means of a tell-tale or smoke generator with a real cambered foil at an angle of attack, it can be seen that the stagnation point, the point at which the airflow divides to pass either side of the foil, is not right at the leading edge, but is some distance around the lower (windward) side, depending on the angle of attack. The purpose of the convexity on the lower (windward) side, I am convinced, is to direct more airflow around the leading edge and upper (lee) side, where it speeds up considerably, lowering its pressure as a result. This is where the majority of the lift of a good foil is generated.

A soft sail simply can't achieve this convexity. However much tension is applied to the cloth, vertically or horizontally, the sail falls inward. It is possible to achieve a round leading edge, under sufficient vertical tension, and if the sail does not twist; but that is of no avail on its own. It is only when the airflow is made to travel around it that it begins to be worthwhile.

And so I come to what is probably the most important thing that I have learnt recently about soft wingsails – it is absolutely necessary to put in “riblets” between the wishbones, to hold the forward part of the sail, the luff round and the first 10% of *both* sides in the designed shape. Here is what I have done:

I have put in three riblets, cut from 2 thick ABS sheet, spaced at 300 apart, between each wishbone. They were rough-cut from sheet, and then a big stack of them was routered to shape with a template, and holes for stitching at 25 apart were drilled. A piece of 50 wide webbing was machine sewn to the sail along its centreline. Each riblet was hand-stitched into place.

(also in this photo (taken from the head of the sail) can be seen the wishbone attachments. Webbing straps with eyes are sewn on at the luff, and are bolted to the underside of the nose. At the sides, lengths of webbing, with small holes made with a soldering iron, are sewn to the sail along their top edges, and are lashed to the wishbones.)

Not difficult, but time consuming. And yet, I now feel that if you don't put the riblets in, there's no point in going to all the trouble of making wishbones and a double sail. They are that important. Here is a photo of the lee side of the mizzen. It stands completely stable, as if it were a hard surface, with no panting or collapsing:

(the lower two panels are twisted, with diagonal creases – I hadn't got the sheeting right at this stage.

A tell-tale ribbon on a stick shows an attached, if turbulent , airflow around the luff and lee side:

One riblet is not enough, but better than nothing. Two riblets are probably enough. Three riblets are a little better than two, but the law of diminishing returns is beginning to apply. It can be seen that even on the loft floor, the luff is perfectly in shape. It might be thought that the riblets will need more space to stack in when the sail is furled, but in fact they seem to disappear between the wishbones.

The battens, at their after ends, are simply bolted through eyes in the sail, flush with the leech.

Each wishbone has a downhaul, either singly or by spanning two together.

The halyard is lead down inside the sail, since the sail is now so thick that it would be bound to rub against the halyard if led outside.

A forward lift just aft of the mast supports the wishbones when the sail is reefed or furled. A pair of topping lifts does the same aft (remembering that the aft ends of all the battens must be aft of the topping lifts at all times – this is the strongest determining factor in the planform of the sail).

Any chinese sheeting system can be used, but as with any cambered junk sail, the top of the sail really has to be hauled up to weather if you are to point high. Centreline sheeting is ineffective. I favour two sheets, port and starboard, with the upper parts led to weather and the lower parts led to the boat's centreline.

The heads of the sails are the only parts that I am not yet satisfied with. I simply added cloth so as to extend the line of the heads of the sails until they met the luffs, and built “head wishbones” from two normal wishbones spaced 100 apart. The halyards are attached to strong tubular bridges.

This has made the luffs a little too long – I should reshape the heads of the sails so that they are at less of an angle to the horizontal. The sails will then furl more readily, too.

The luff of the mainsail above the top batten does not have enough support, and I should add another wishbone here.

The hardest part of the whole rig to get right is the position of the mast bearing in the head wishbone. It bears against the forward side of the mast, whereas all the lower wishbones thrust against its after side. Since the mast is tapered, the offset varies as the sail is hoisted and lowered. Trial and error, and some adjustability of the head mast bearing, are needed to get an acceptable result.

But all in all, I've achieved what I set out to do:

- Enough camber to drive *Tystie* through an awkward sea
- The all-important first 10% of both sails holds to the designed shape, even when pitching
- The foil section is maintained right to the heads of the sails
- The battens all articulate freely, even though the angle of articulation has increased from 15° to 23°
- More area in the mainsail has improved the helm balance
- The weight of the complete set of battens has decreased by 20kg
- And most importantly, *Tystie* sails closer to the wind and faster than she did before. I can't yet give meaningful figures, except to say that sailing against *Footprints*, a lighter boat with a longer waterline, and with a Hasler style junk rig, *Tystie* was 1 or 2 knots faster to windward, pointing 10 to 15° higher (David Thatcher, the owner of *Footprints*, now intends to build a wingsail!). Now I need an equivalent size of bermudan rigged boat to sail against...

Tystie, with her updated rig, sailing well to windward.