Rig Design

The rig is designed so that in 20 *kt* of apparent wind the boat heels about 25°, without need of reefing. I had initially planned for a 7/8 fractional rig with a 125% overlapping jib. When developing all the calculations, I found that this configuration needs 3 spreaders, plus jumpers at the headstay attachment, in order to keep the dimension of the mast section within reasonable limits.
I decided then to develop a rig design where the shrouds chainplates could be all the way out to the edge of the deck with a non-overlapping jib. The larger chainplate width greatly reduces the compression in the mast, thus allowing for the use of only 2 sets of spreaders plus the jumpers. Moreover, because of the twist of the jib leech, it is possible to use a 110% jib and still it fits under the lower spreader.
Both masts are tapered above the last set of spreaders and have non-structural running backstays to control the mast bending for maximum performance.
Approximate drawing of both sailplans, respective structural calculations, and mast and boom section are included in the appendix.

Main Dimensions	**110% Jib**	**125% Jib**
Mast height above the deck, I [m]	19.10	18.75
Mast distance from stem, J [m]	5.50	5.50
Mast transverse dimension, MT [m]	0.10	0.10
Mast Longitudinal Dimension, ML [m]	0.20	0.20
Boom height above the deck BH [m]	1.20	1.20
Boom length, E [m]	6.60	6.50
Mainsail luff P [m]	17.90	17.55
Mainsail Aspect Ratio, P/E [m]	2.71	2.70
Jib halyard height above deck IM [m]	16.71	16.41
Jib luff JL [m]	16.00	15.59
Jib foot JF [m]	6.05	6.88
Jib Aspect Ratio, JL/JF [m]	2.64	2.27
Height of lower spreader, HSL [m]	0.00	5.80
height of middle spreader, HSM [m]	6.70	10.00
Height of upper spreader, HSU [m]	12.20	14.00

Table 3 Main rig dimensions for both configurations considered.

Construction

In agreement with the design philosophy of creating a fast cruiser, I decided to use sandwich construction to save on weight, that can then be use to make the interior more complete and comfortable.
The skins are made of polyester resin reinforced with E-glass fibers, while the core is polyvinyl chloride foam. All the structural elements are dimensioned to comply with the American Bureau of Shipping classification rules for Offshore Racing Yacht. A lighter and more efficient structure could, most likely, be designed if a finite element analysis of it were performed. ABS rules have different requirement for the upper and lower part of the hull, thus resulting in different sandwich thicknesses, as seen in Figure 3.

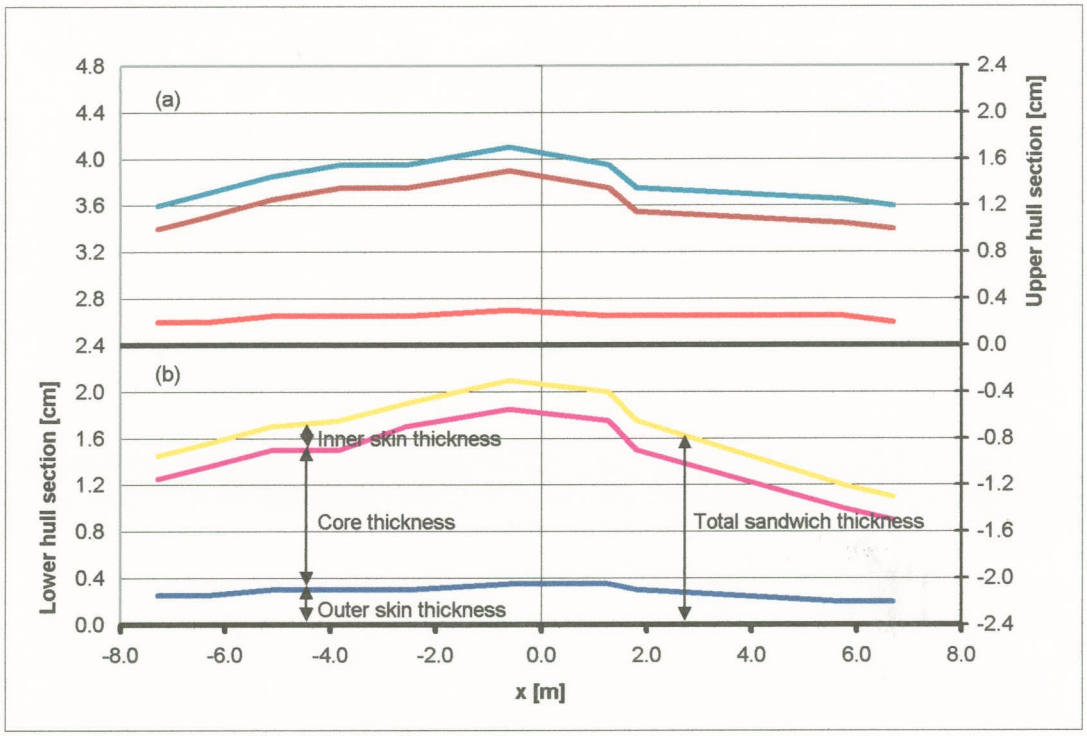

Figure 3 Sandwich thickness for (a) upper and (b) lower hull sections.

The calculations, included in the appendix, were performed using 10 stations along the length of the yacht in order to get a weight as accurate as possible. Similar calculations were also performed to find the sandwich dimensions for the deck.

Once defined the sandwich, it was possible to calculate the required dimensions for the stiffeners. Due to the lack of time only 4 stations were used in this case and the dimensions were found for the worst case. The geometry used is the one shown in Figure 3.1 in the ABS rulebook.

Interior

The interior is designed to accommodate comfortably eight people.

Master Cabin

The master cabin is located in the bow with a 2.1x1.6/0.9 m double berth, with access to the space below provided via cut out hatches. In the port aft side of the berth a wardrobe for hangers, while on the starboard a second wardrobe has shelves, drawers and a bar for hangers.

Head Compartment

The head, on the port side, has sink, toilet and shower, and can be made private for the master cabin by locking the second door.

The second head is located on the starboard side right in front of the mast.

Main Cabin

Moving aft into the main cabin, on the starboard side, a longitudinal 2.1x0.55 m sofa can be converted into a double berth. On the opposite side, a "U"

shaped sofa and a longitudinal one provide seating for eight at the trapezoidal shape table.

Galley

Right next to it the "L" shaped galley with 3-burner propane stove with oven, double sink, and icebox equipped with electric cooling compressor and plate. Cabinets above and below the stove and the sink provide storage space for pots and pans and stores.

Navigation Area

It includes 1.0x0.6 m chart table with space underneath for charts and navigational equipment, shelves for book storage and drawers on the side for tools or other equipment.

Aft Cabins

Two symmetrical cabins have each a 2.1x1.5/1.2 m double berth and a wardrobe with drawers and a bar for hangers.

Engine Room

The Yanmar diesel engine is equipped with Saildrive driving a 2-blade racing Flex-O-Fold 18x14 *in* propeller. The 76 *HP* output should guarantee a good cruising speed.

Deck and Cockpit

The cockpit has longitudinal seating on each side plus a transverse seat behind the steering wheel. The mainsail traveler is mounted on the seats in front of the steering column. Under the back seat and aft part of the longitudinal seats, lockers provide storage space. Two winches on each side of the cockpit serve the main sheet and the jib/spinnaker sheet. Two smaller winches mounted on top of the cabinhouse serve the halyards and the trimming lines.

On the bow, an anchor locker houses the 20 Kg the CQR anchor and relative chain and rope. A windlass is mounted right next to the locker.

Large Angle Stability Analysis

This was performed using Hydromax. As Figure 4 shows, the righting arm reaches its maximum at 53.4° and stays positive up to 127°.

Weight Balance

The total displacement is considered to include the weight of the crew, so an average weight of 95 Kg per person is considering in the calculation for finding the position of the center of gravity of the boat. The keel is positioned right in front of amidships with the mast stepped at the same longitudinal as the leading edge at the root, in order to balance the hydro and aerodynamic centers of effort.

The longitudinal and transverse position of the center of gravity is adjusted by moving the internal ballast, so that the CG and CB are aligned. Actually the static CG is position about 0.1 *m* aft of CB to compensate, at least in part, the pitching moment created by the sails.

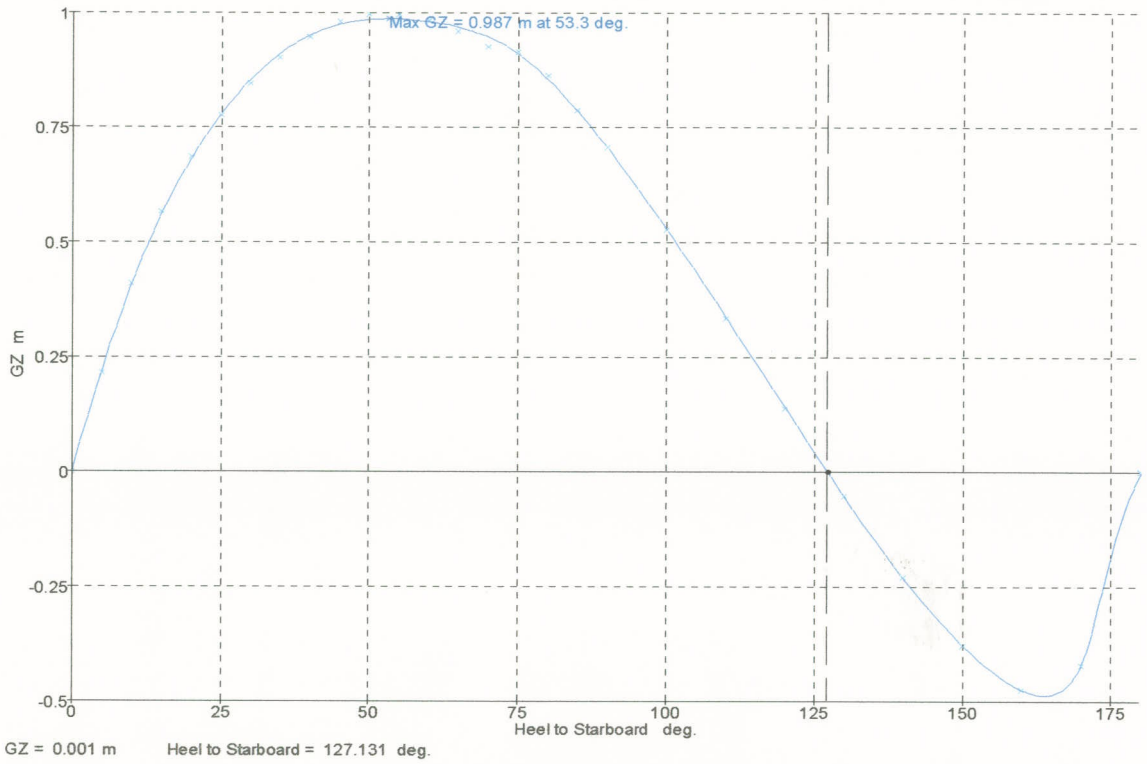

Figure 4 Righting arm curve.

Performance

In the polar performance graph in the Appendix, the yellow lines represent the yacht upwind in 6, 8, 10, 12, 14, 16, and 20 knots of true wind, while the cyan lines represent the yacht performance when the spinnaker is being used.

In 14 *kt* of true wind, equivalent to about 20 of apparent wind, the optimum upwind angle is predicted by Span to be between 39° and 42°, angle at which the yacht reaches a speed of 7.5 *kt*, with a VMG of 5.7 *kt*. In this wind condition the heel angle is about 22.5°, less than the 25° for which the rig was designed. However this was expected because the righting moment for the rig design was obtained from Hydromax assuming that the CG was on the DWL. Since the center of gravity resulted to be 17 *cm* below it, the Span results seem reasonable.