Appendages

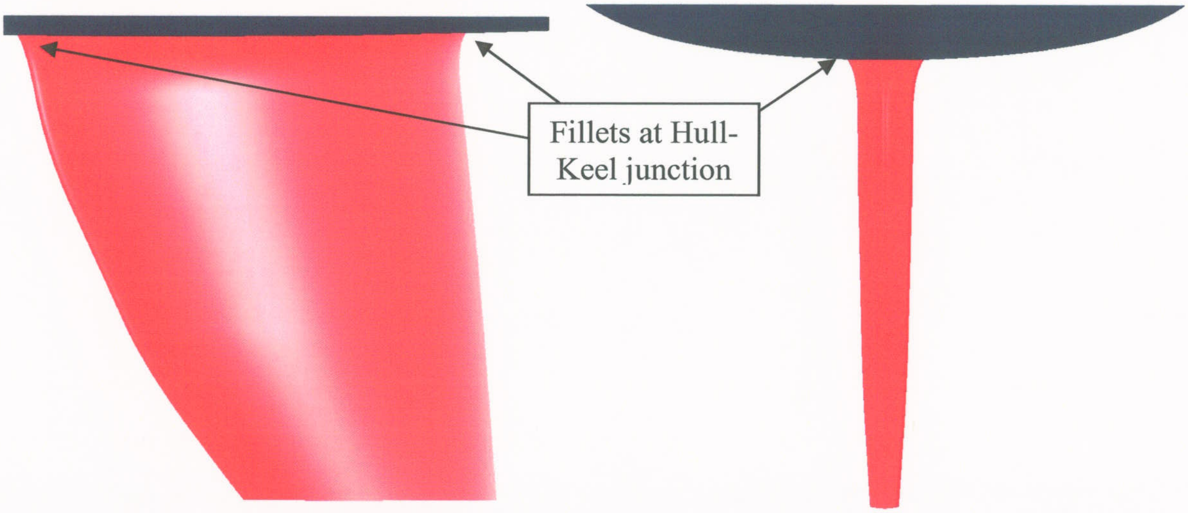
Keel

In order to simultaneously meet the requirements of keel area to sail area ratio of 3%, and maximum draft of 2.8m (corresponding to a keel span of 2.2m below Tc), the keel must have a relatively large average chord. A NACA 65 section profile is selected in order to minimize the drag at low angles of attack (when beating upwind). The chord at the root of the keel is 2.05m and decreases to 1.2m at the tip, leading to a taper ratio of 0.59. The chord first decreases slowly then faster, in order to meet the keel area requirement and to approximate an elliptic shape. The 25% chord line is very slightly swept back.
The displaced volume requirement imposes a thickness to chord ratio of 14%. This ratio is kept constant over ¾ of the span, and then drops to 12% at the tip.
The displaced volume of this keel is 0.592m3, slightly larger than in the preliminary design (0.562m3). Here, we assume that 90% of the keel volume is available for the ballast. Completely filling the keel with lead leads to a ballast mass of 5861kg, and thus a ballast to displacement ratio of 45%. From the hydrostatics calculation, we find that the VCB of this keel is at -1.5m below the design waterline. Since the keel is completely filled with lead, this is also the VCG of the ballast, and we will assume for the weight balance and VCG computation that this is also the VCG of the keel shell. The longitudinal position of the keel is adjusted simultaneously with the rig design in order to achieve the desired longitudinal balance (lead). This will be detailed in the Balance section.
Table 3 summarizes the main characteristics of the keel. The keel shape can be seen on the profile view of the hull with deck and appendages, in appendix 4.

Span (from Tc)	2.20	M below Tc
Area	3.97	m2
%SA	3.0%	
ARe	2.44	
Taper ratio	0.59	
Wetted Surface	7.947	m2
Displaced volume	0.592	m3
LCB	-6.736	m aft from FP
VCB	-1.498	m below WL
	Chord (m)	t/c
Root	2.05	14%
¼ span	2	14%
½ span	1.8	14%
¾ span	1.6	14%
Tip	1.2	12%

- Table 3: main characteristics of the keel -

In order to improve the hydrodynamic performance, we put fillets at the keel/hull junction.
The keel geometry is shown on Figure 3.



- Figure 3: two perspective views of the keel-

Rudder

The rudder is based on a NACA 4-digit profile in order to have a more tolerant hydrodynamic performance, ie. that the drag increases progressively with the angle of attack, and that it does not suddenly stall. The rudder span is 2.2m, and the chord varies form 0.8m at the root to 0.4m at the tip (taper ratio of 0.5), with a maximum of 0.82m at 25% of the span. This leads to a rudder plan form area of 1.2% of the total sail area. The thickness to chord ratio progressively decreases from 17% at the root to 12% at the tip. This high thickness ratio at the root is imposed by the structural constraints on the rudder stock: according to the ABS rules, this rudder requires a stock diameter of 11.6cm. The thickness of the rudder at the root is 13.6cm, which should provide enough room for the stock.

The displaced volume of this rudder is 0.11m3. This leads to a total displaced volume of 12.624m3 (mass of 12939kg), slightly larger but very close to the initial design (12.610m3/12925kg).

Table 4 shows the main characteristics of the rudder. The rudder shape can be seen on the profile view of the hull with deck and appendages, in appendix 4.

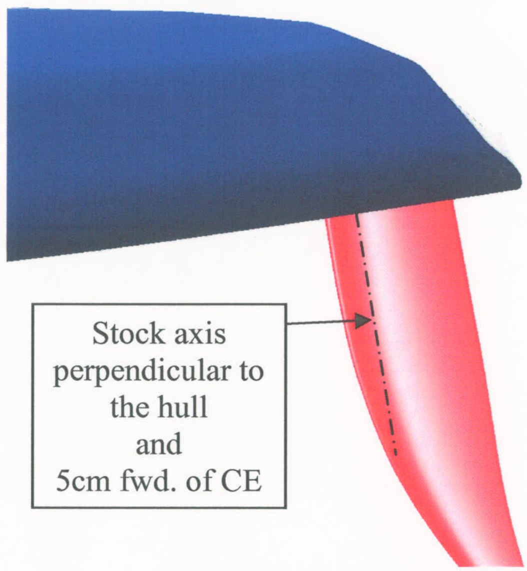
Span (from DWL)	2.20	m
Area	1.6	m2
%SA	1.2%	
ARe	6.04	
Taper ratio	0.5	
Wetted Surface	3.205	m2
Displaced volume	0.11	m3
LCB	-13.71	m aft from FP
VCB	-0.889	m below WL
	Chord (m)	t/c
Root	0.8	17%
¼ s	0.82	15%
½ s	0.8	14%
¾ s	0.6	13%
Tip	0.4	12%

- Table 4: main characteristics of the rudder-

The rudder is slightly swept back such that the rudder stock can simultaneously:

- pass 5cm (=2inches) forward of the hydrodynamic center of efforts of the rudder (CE at 25%chord at 45% span, shown on figure 1) in order to achieve a good rudder balance and
- be perpendicular to the hull bottom so that the rudder can be trimmed at any angle without touching the hull or opening a wide gap at the rudder-keel junction.

A consequence of the back sweep is that the center of efforts is further aft for the same root position, and thus leads to a larger lever arm and more "control" of the boat.
The rudder geometry is shown on figure 4.



- Figure 4 -

Rig

In order to achieve a reasonable Dellenbaugh angle, close to 16 degrees, with the relatively stable hull and such a deep keel, this boat requires a large sail area. We choose to have a large main sail (130% of the jib area), with a 7/8 fractional rig and a 110% overlapping jib.
The boom height is such that the clearance in the cockpit is about 1.9m. This leads to a reasonable clearance of about 70cm at the roof, so that the crew can easily pass under the boom when tacking. Two spinnaker sizes are considered: one for moderate to strong winds (110m2), and a very large masthead spinnaker of 180m2, for light to very light winds.
The main rig design parameters are shown in Table 5.

The structural requirements are computed according to the Henry & Miller method for the mast and the shrouds. The details of the computation and the resulting requirements are shown in Table 6. In order to decrease the mast compression, and thus be able to choose a smaller and lighter mast section, the two spreaders are back swept, such that the chain plate half-width is 1.91m. This allows selecting a mast section of reasonable dimensions and weight as proposed by the manufacturer Selden Mast AB. The boom is selected among the Sailnet store. The main characteristics of the mast and boom sections are shown on figure 5 and in Table 7.
Table 8 and 9 show the resulting shrouds and spreaders characteristics.

Rig Design Parameter	
Mast span (m above WL)	21.7
Mast longitudinal position (m fwd amid.)	1.5
Jib overlap	1.1
Boom height (m above WL)	2.5
Boom length / main foot (m)	7.1
Fractional rig ratio	7/8
Jib actual area (m2)	56
Jib VCP (m)	8.62
Jib LCP (m fwd amid)	3.45
Jib height (m) I	17.55
Jib foot (m)	6.38
Fore triangle (m) J	5.8
Main triangular area (m2)	67.98
Main actual area (m2)	75.6
Main VCP (m)	10.3
Main LCP (m fwd amid)	-0.53
Main luff (m)	19.15
Jib-Main area distribution	43%-57%
Total actual sail area (m2)l	131.6
Total VCP (m)	9.56
Total LCP (m fwd amid)	1.16
Downwind Sail area (m2)	186 (fractional spi) 253 (masthead spi)

- Table 5: Sailplan dimensions -

GZ30	0.81	m	
RM30	10482	kg.m	From Hydromax
Chainplates half-width	1.910	m	
Chainlpates load	79946	N	
Mast compression	147900	N	
Spreader 1 height above deck	7.5	m	
Spreader 2 height above deck	13	m	
Forestay attachment height above deck	17.8	m	
Mast height above deck	20.4	m	

	C	P (lb)	L (in)	Required I (in4)	Required I (cm4)
Lower panel	1.13	33500	295.28	33.0	1374
Middle panel	1.69	33500	216.5	26.5	1105
Upper panel	1.69	33500	189.84	20.4	849
Fore and Aft panel	0.52	33500	691.1	83.2	3463

- Table 6: transverse and longitudinal panels geometry and moment of inertia requirements -