13.714 – Sailing Vessel Design

Spring 2002

Problem Set 4:

Final Design of a 14 Meter Cruiser/Racer Yacht

by

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Design Philosophy

This design is intended to be a fast, modern cruiser/racer, meaning a yacht with all the amenities necessary to make cruising pleasant, but that can be also successfully raced under the IMS handicapping system.
With this objective in mind, in the preliminary design, I decided to set the waterline length L_{WL} to 12.8 *m*, with a fixed overall length L_{OA} of 14 *m*, using a very short overhang at the bow and a longer one at the stern. I then picked a prismatic coefficient C_P of 0.54 because I want to design a boat with a good compromise of performance for both light and strong winds. AS a result of a design study, a displacement to length ratio of 135 and a beam to length ratio of 3.5 were chosen.

Hull Form

Table 1 compares the major design characteristics between the preliminary design and the final design. As seen, the final design developed respects all the dimensions set in the preliminary stage of the design, except for the appendage volume and, therefore, for the total displacement. This happened because I did not include the rudder volume in the preliminary calculation. In fact 0.414 m^3 was chosen as keel because if filled with lead is about 45% of the total displacement. The final keel has a volume of 0.418 m^3.

	Preliminary Design	Final Design
Total Displacement, Δ [Kg]	10161.9	10253.1
Canoe Body Displacement, Δ_{CB} [Kg]	9737.5	9736.6
Canoe Body Volume, ∇_{CB} [m^3]	9.5	9.499
Appendage Volume, ∇_A [m^3]	0.414	0.501
Waterline Length, L_{WL} [m]	12.8	12.801
Waterline Beam, B_{WL} [m]	3.657	3.658
Draft, T [m]	0.471	0.47
Prismatic Coeff., C_P	0.54	0.54
Max Sectional Area, [m^2]	1.374	1.374
Center of Gravity, KG [m]	0.471	0.3
Righting Moment at 1 deg [Kgm]	432.5	448

Table 1 Design characteristics.

The line drawings in the appendix show how the sections are designed to have a "V" shape forward of the keel and a wide "U" shape from thereto the stern. The bottom is relatively flat, with a rather hard bilge right under the designed waterline. In the bow, below the DWL, there is a little bit of hollow, so to make the boat more seakind, that disappears as we move upward in order to have more reserve buoyancy. In profile view, the boat has an almost plum, straight stem, forward raked transom, and a very limited sheer.
The resulting sectional area curve for the canoe body, in Figure 1, shows the hollow in the bow section, a linear part in front of the midship section where the keel will be attached, and an almost linear section in the aft part.

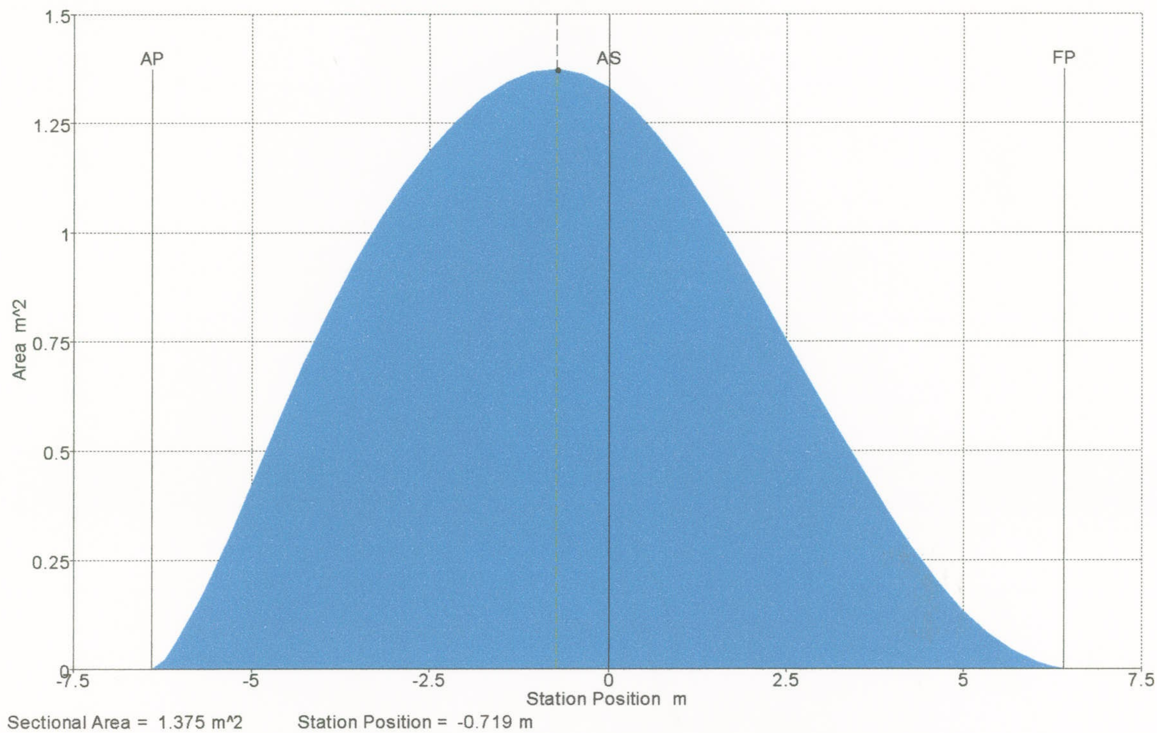

Figure 1 Canoe body sectional area curve.

	Upright	Heeled
Draft Amidsh. m	0.469	0.342
Displacement kg	10179	10179
Heel to Starboard degrees	0	25.04
Draft at FP m	0.466	0.472
Draft at AP m	0.471	0.212
Draft at LCF m	0.469	0.327
WL Length m	12.8	13.358
WL Beam m	3.656	2.86
Wetted Area m^2	43.84	38.596
Waterpl. Area m^2	32.287	25.452
Prismatic Coeff.	0.47	0.444
Block Coeff.	0.074	0.102
Midship Area Coeff.	0.173	0.242
Waterpl. Area Coeff.	0.69	0.666
LCB from Amidsh. (+ve fwd) m	-0.627	-0.629
LCF from Amidsh. (+ve fwd) m	-1.004	-0.731
KB m	0.22	0.036
KG fluid m	0.3	0.3
GMt m	2.516	1.393
GML m	27.812	23.267
Max deck inclination deg	0	25.1
Trim angle (+ve by stern) deg	0	-1.2

Table 2 Free-floating hydrostatic data.

Table 2 shows Hydromax free-floating analysis result for the boat upright and heel about 25° (this second condition is achieved by arbitrarily moving the CG to one side) for the yacht with the original displacement. The difference in displacement results in a floating waterline 0.001 *m* below the DWL. Even at 25° heel the boat is still well balanced, as it assumes a trim by the bow of only 1.2°.

Appendages

I wanted to have a bulb keel, so to maximize the righting moment, and therefore been able to carry more sails. The keel was developed starting from a NACA 64 series profile. The fin has a chordlength of 1.4 *m* and a thickness-chord ratio of 15% at the root, and of 0.85 *m* and of 14%, respectively, at the intersection with the bulb. It is slightly swept aft, so that the trailing edge is straight and vertical. The bulb maintains the same profile as the fin, but it has a maximum length of 1.77 *m* and a maximum width of 0.42 *m*. The total span is 2.4 *m*, but thanks to the bulb the center of buoyancy is 1.31 *m* down from the root.

The rudder is designed too with a NACA 64 series airfoil shape, with a root chord of 0.58 *m* and a tip chord of 0.38 *m*. The maximum chord of 0.71 *m* is reached at about 45% of the 2.1 m span. The thickness ratio at the root was 17%, so to fit a 0.1 *m* diameter stock, but it is already down to 15% 0.4 *m* from the root and 14% at 0.7 *m*. This value is then maintained for the rest of the span.

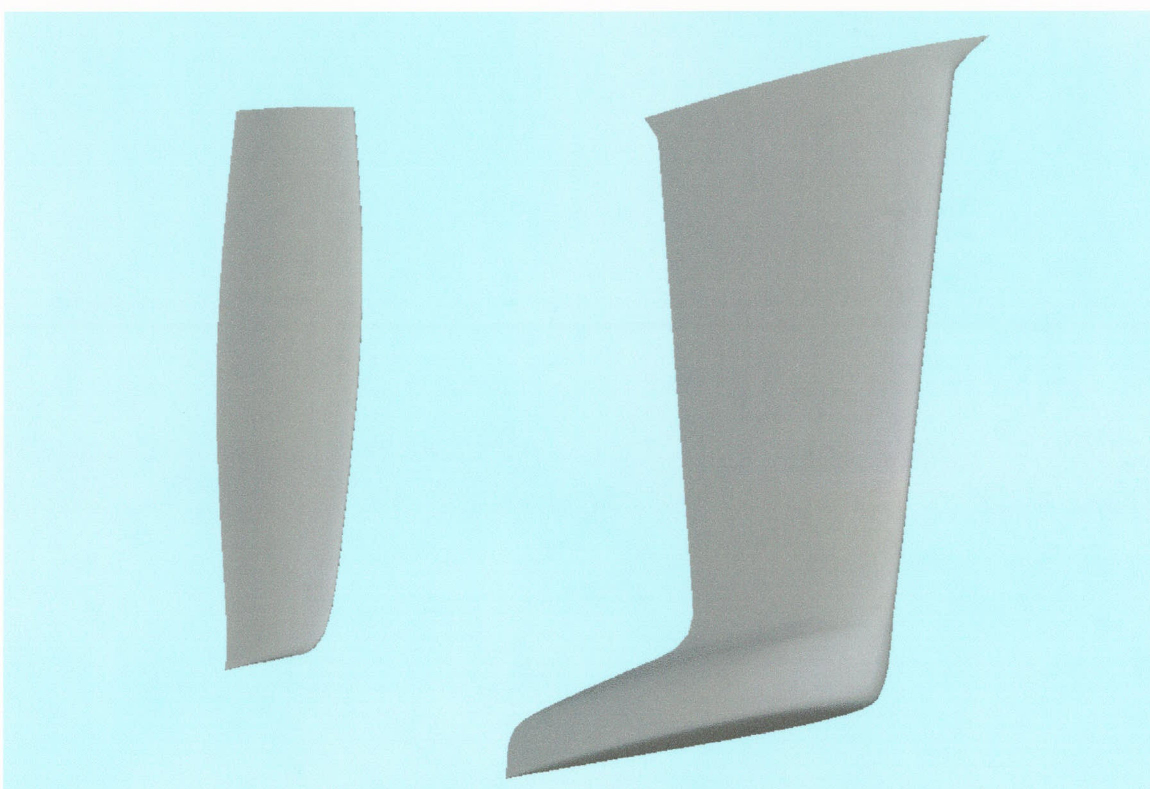

Figure 2 Bulb keel and rudder.