Tutorial – Use of Gene-Hull UE 2,3 for an early stage project

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Objective of the tutorial :

To generate step by step a hull, with a sailplan and a weight first estimation, for an early stage project of sailing yacht with given objectives.

Through this approach, it is to show how to introduce step by step the input data, how to analyse the output data, how to iterate and to improve the design.

The starting point is the so-called reference boat of which input data are in place in the application to help the beginning of a new project.

The objective for this tutorial exercise is a cruiser yacht of which characteristics are inspired by the Delher 34 2017 :
Loa (Hull) 10,30 m ; Lwl 9,60 m ; B 3,60 m ; Draft 1,95 m ; Keel-bulb 2100 kg ; Displacement : 5950 kg
Sailplan : Rig : I = 13,60 m ; J = 3,87 m ; P = 13,25 m ; E = 4,95 m ;
Other geometrical data (free boards, mast height, boom height, ...) are estimated from the Delher 34 brochure : https://www.yachts.group/gb/dehler/boats/dehler-34.html

This tutorial boat will be named **« Tut 34 »** , and the hard chine version is named **« Tut 34 HC »**

Three parts :

Part 1 : a first design (with rounded U sections) >>> Tut 34

Part 2 : a second improved version (with introduction of a hard chine) >>> Tut 34 HC

Part 3 : summarize of the final version Tut 34 HC

Part 1 : a first design (with rounded U sections)

You start from the data already in place (the so-called hull of reference).

To begin by the input of the geometrical data, then to adjust by using the adimensional parameters acting on the shape, and finally a fine tuning using both type of input data.

Such data introduction step by step can lead, at each step, to bizarre shapes of the hull till all new data are not put and in coherence. Don't worry about that, the process usually does not bug and you can continue the data introduction. In the tutorial here below, I show you the hull progressively evolving from the reference one to the new one at each new step.

Step *1* Input of the longitudinal X's of the keel line, the sheer line and the deck central line

Keel line :

Lwl = 9,60 m, i.e. the objective value.

Xbow = 9,70 m, so a quasi plumb bow (9,7 – 9,6). Xbow should be > Lwl

Xtab ar = -0,60 m, so 9,7 + 0,6 = the objective Loa 10,30 m. X tab ar should be < 0

Sheer line :

X liv ar = - 0,2 m sheer line rear end

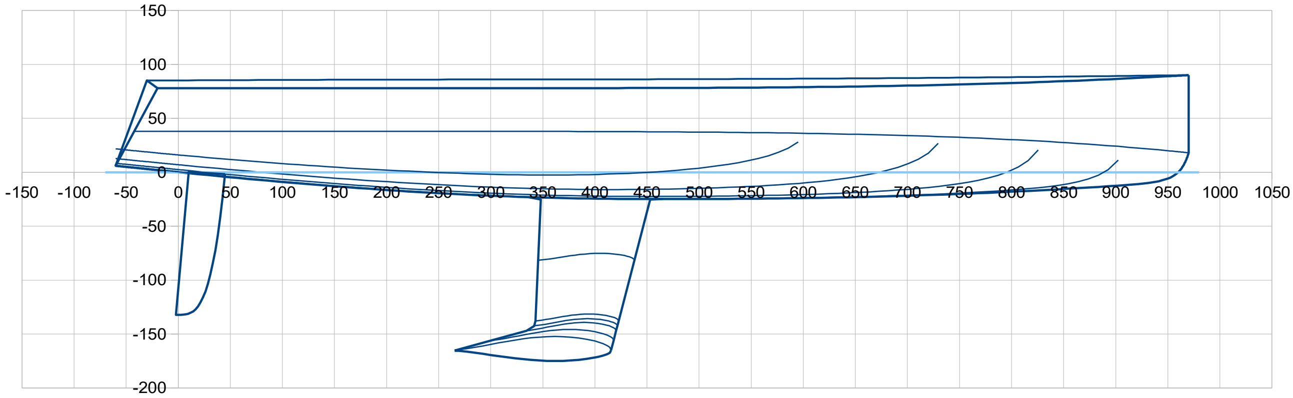
Deck central line :

X p ar = -0,3 m deck line rear end (Conditions : X tab ar < X p ar < X liv ar < 0)

>>> the corresponding input data :

Lwl (m)	**9,60**
Xbow (m)	**9,70**
X tab ar (m)	**-0,60**
X liv ar (m)	**-0,20**
X p ar (m)	**-0,30**

>>> The longitudinal view after this stage :



***2* Put the vertical Z's of the keel line, the sheer line and the deck central line**

Keel line :

Zbow = 1,20 m , the fore freeboard

Tc = 0,4 m , the hull body draft, a very preliminary value at this stage.

at **X Tc = 50 % Lwl ,** the X position of Tc, idem preliminary value

Z tab ar = 0,1 m , rear transom aft end , very preliminary value

Sheer line :

Z liv m = 1,05 m , the freeboard at 35% Lwl

Z liv ar = 1,05 m , the aft freeboard

Deck central line :

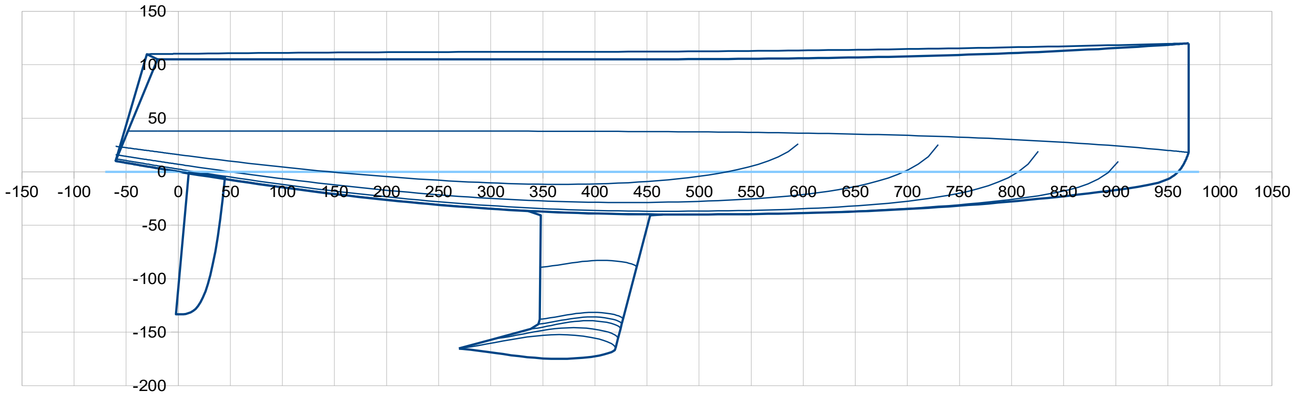
Z p m = 1,12 m deck line height at 35% Lwl

Z p ar = 1,10 m deck line rear end height

>>> the corresponding input data :

Zbow (m)	**1,20**
Tc (m)	**0,400**
X Tc (%Lwl)	**50,00**
Z tab ar (m)	**0,100**
Z liv m (m)	**1,05**
Z liv ar (m)	**1,05**
Z p m (m)	**1,12**
Z p ar (m)	**1,10**

>>> The longitudinal view after this stage :



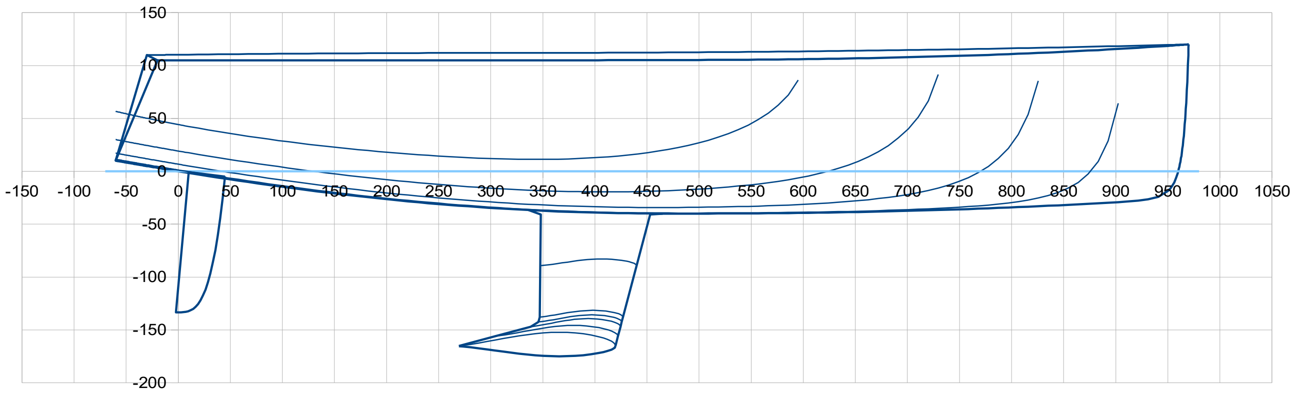
***3* No hard chine for this first part of the tutorial**

To disconnect the hard chine option, it is sufficient to input **Type = 0**

>>> to input :

Type	**0**

>>> >>> The longitudinal view after this stage :

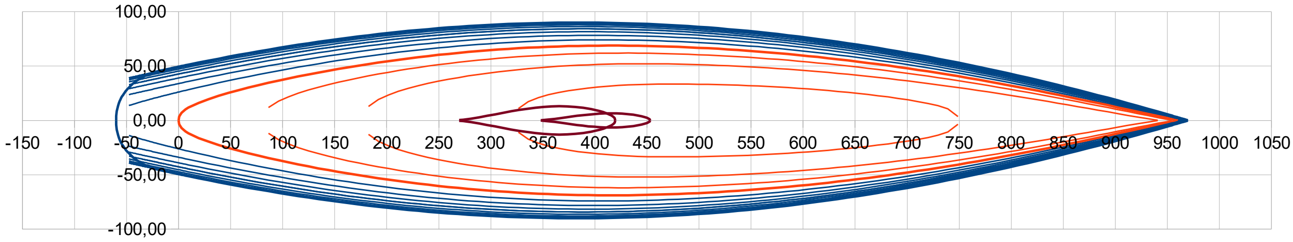


***4* Sheer line first definition in horizontal projection xy**

The objective is to have a sheer line with its maximum beam very aft, positioned at around 25% Lwl, typical of such modern racer/cruiser hull. Such sheer line can be generated using the alfa transformation of Gene-Hull : a first generation of a generic hull (which looks like a classic slender one) and then open it by a rotation with the bow end as the center of this rotation. For such objective, I recommend to build at first a « generic » hull with Bg equal to about half the objective Bmax, so **Bg (m) = 1,80** with, for all other sheer line parameters :
X Bg (%Lwl) = 40 ; alfa(°) = 0 ; Pui liv y = 2 ; Cor pui liv = 0,02 ; Pui cor pui = 1 ; Scow = 0
>>> to input :

Bg (m)	**1,800**
X Bg (% Lwl)	**40,0**
Alfa (°)	**0,000**
Pui liv y	**2,00**
Cor Pui liv	**0,020**
Pui Cor Pui	**1,00**
Scow	**0,00**

>>> The hull waterlines after this stage :



***5* Sheer line adjustment using the alfa transformation**

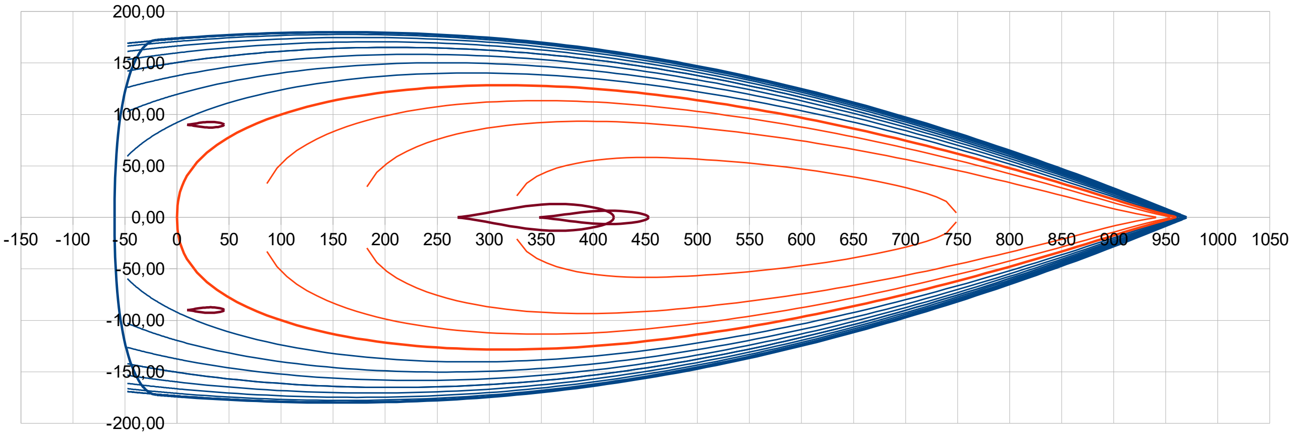
From this starting point above, we can now iterate with alfa (the half angle of the rotation) and the generic beam Bg in order to have the maximum beam Bmax equal to the objective 3,60 m and positioned aft at 25% Lwl. At each step, Bmax and its position Xb (%Lwl) are computed and indicated in blue on the right side of the input data.

Bg (m)	**1,800**				
Alfa (°)	**5,000**	**>> Bmax (m)**	**2,96**	**at Xb(%Lwl)**	**24,0**

Bg (m)	**1,800**				
Alfa (°)	**7,000**	**>> Bmax (m)**	**3,50**	**at Xb(%Lwl)**	**17,0**

Bg (m)	**1,800**				
Alfa (°)	**7,350**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**16,0**

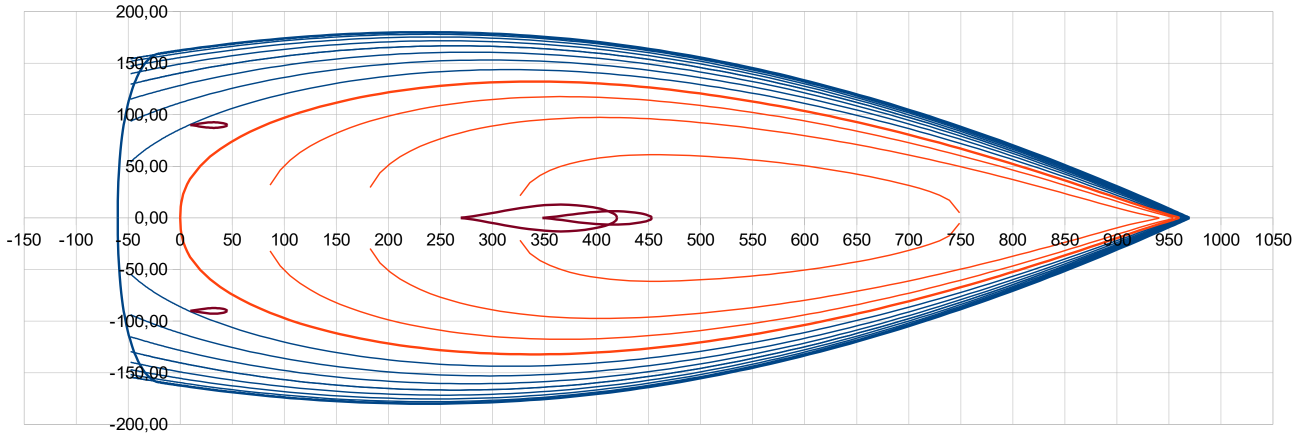
>>> drawing at this stage :



At this point, one can consider that the Bmax is a bit too aft, at 16% Lwl instead of about 25 %, so one can increase Bg and decrease alfa up to reach this objective :

Bg (m)	**2,000**				
Alfa (°)	**6,000**	**>> Bmax (m)**	**3,40**	**at Xb(%Lwl)**	**23,0**

Bg (m)	**2,210**				
Alfa (°)	**6,000**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**25,0**



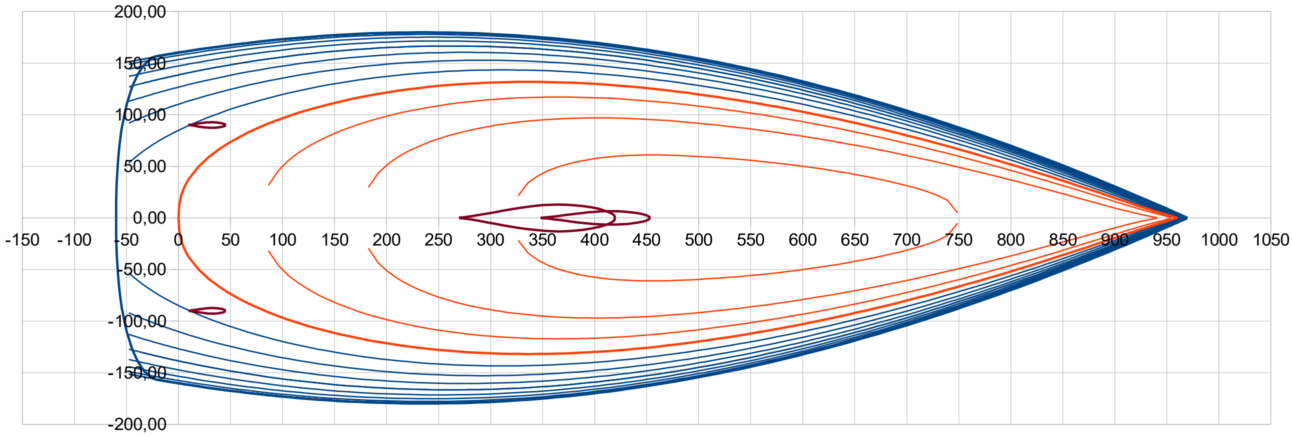
From this very first sheer line shape, now one can test the influence of the other parameters on the shape.

6 Sheer line adjustment using X Bg

At this stage, it is worth to test the influence of X Bg to improve the shape of the sheer line :
>>> Tests with X Bg = 30, 40, 50, 60 and 70 and for each case the adjustment of Bg and alfa in order to maintain Bmax = 3,60 m and Xb = 25 % Lwl.

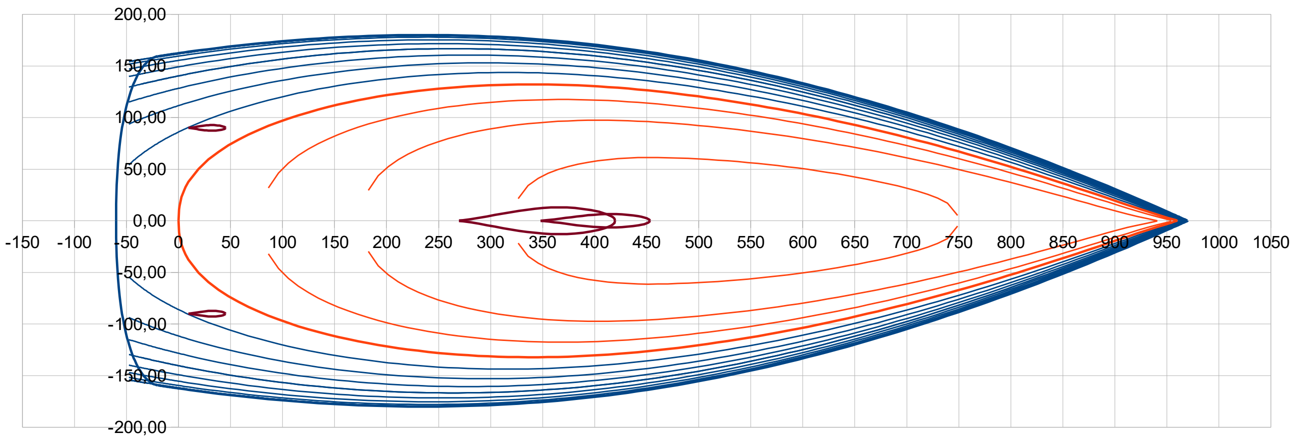
With X Bg = 30 :

Bg (m)	**3,050**				
X Bg (% Lwl)	**30,0**				
Alfa (°)	**2,200**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**25,0**



With X Bg = 40 :

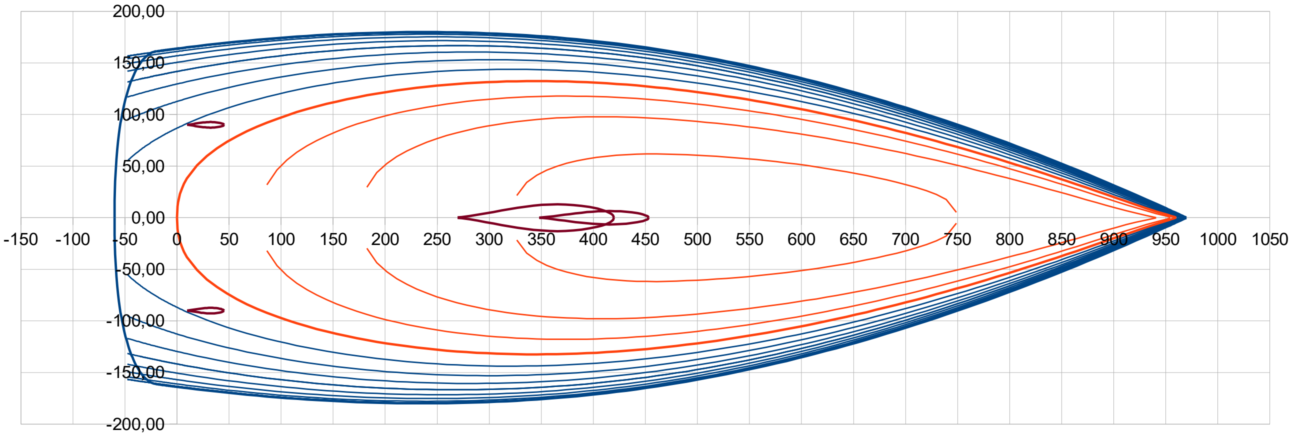
Bg (m)	**2,210**				
X Bg (% Lwl)	**40,0**				
Alfa (°)	**6,000**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**25,0**



With X Bg = 50 :

Bg (m)	1,560
X Bg (% Lwl)	50,0
Alfa (°)	9,550

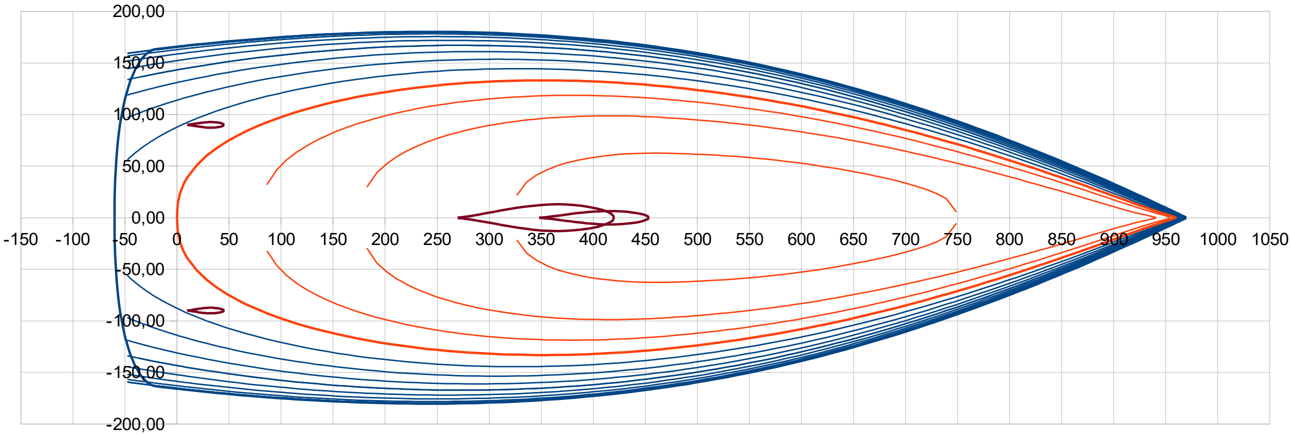
>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



With X Bg = 60 :

Bg (m)	1,070
X Bg (% Lwl)	60,0
Alfa (°)	13,150

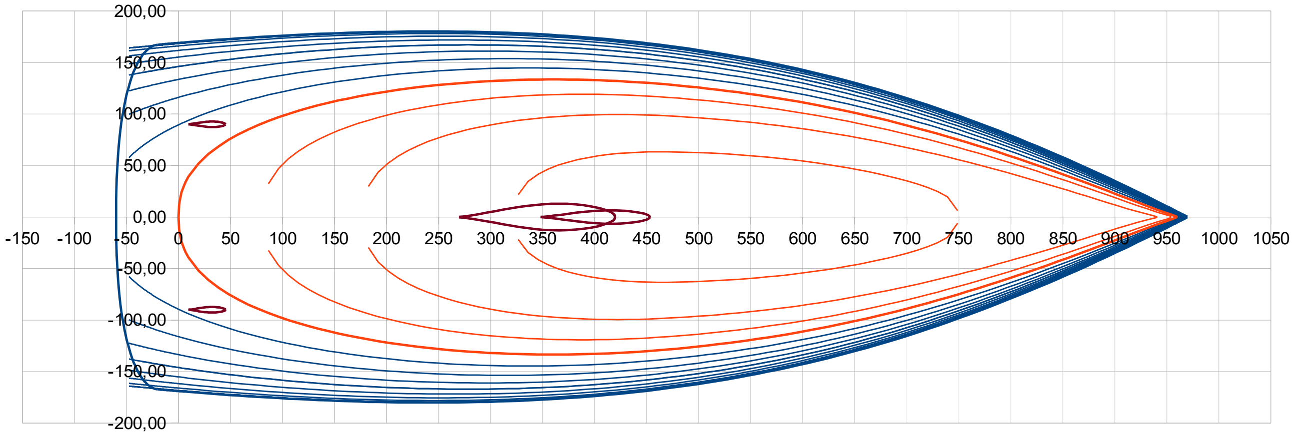
>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



With X Bg = 70 :

Bg (m)	0,690
X Bg (% Lwl)	70,0
Alfa (°)	17,150

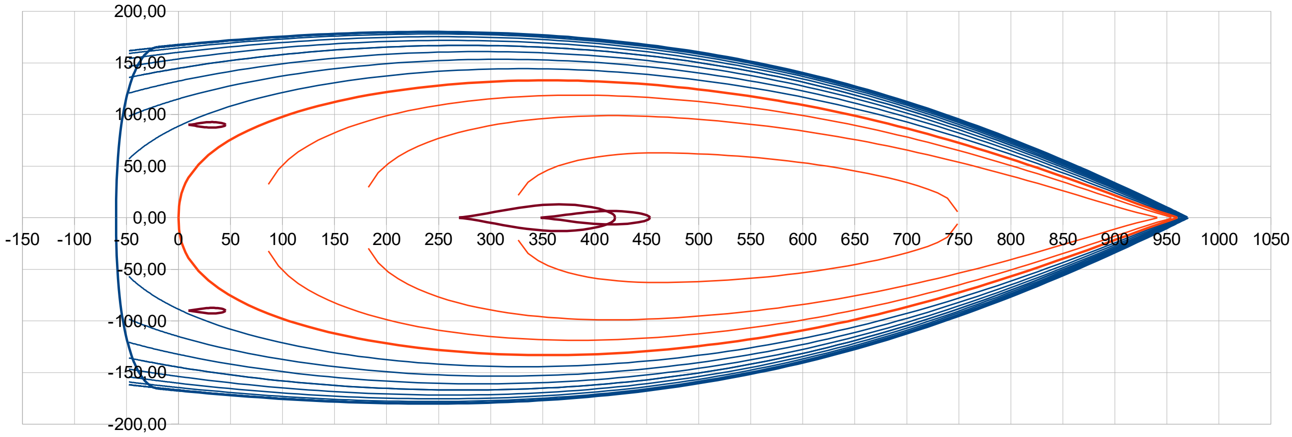
>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



One can see that the maximum curvature of the sheer line moves forward with X Bg. At this stage, one can consider that an X Bg between 60 and 70 can give a good shape, so let's consider **X Bg = 65 :**

Bg (m)	**0,860**
X Bg (% Lwl)	**65,0**
Alfa (°)	**15,050**

>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



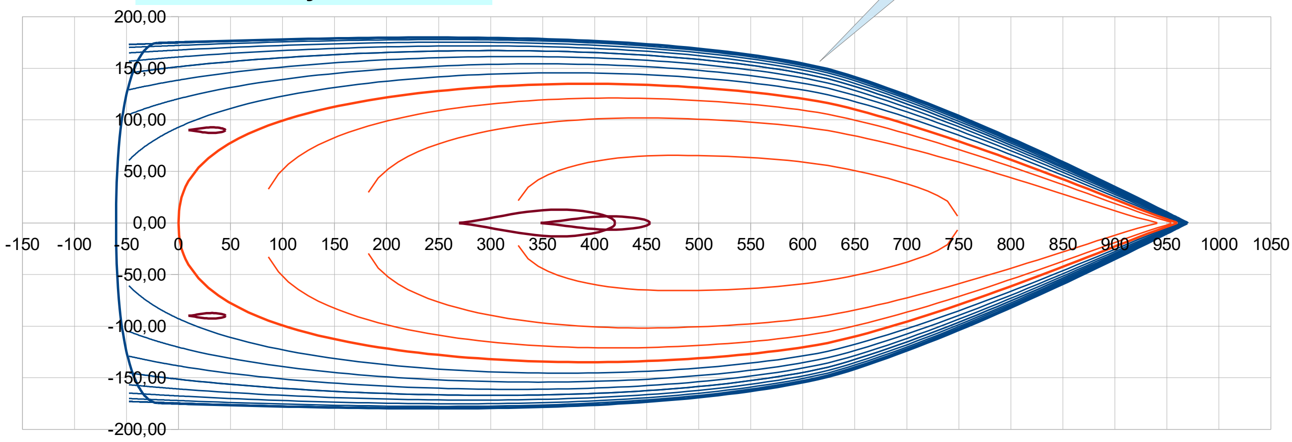
7 Sheer line adjustment using Pui liv y

« Pui liv y » is the main degree of the sheer line polynomial. To take Pui liv y = 2 is highly recommended as this lead to the greatest regularity of the curvature all along the sheer line. To take < 2 increase the maximum curvature at X Bg, up to a folding effect. To take > 2 introduce a relative flatness at X Bg and so two maxima of curvature in the sheer line, which is not very good too. In order to show this influence and why 2 is highly recommended, here below tests with Pui liv y = 1,6 , 1,8 , 2,0 , 2,2 and 2,4 and for each case adjustement of Bg and alfa to maintain Bmax = 3,60 m and Xb = 25 % Lwl.

With Pui liv y = 1,60 : the folding effect of the sheer line is very visible … Folding effect

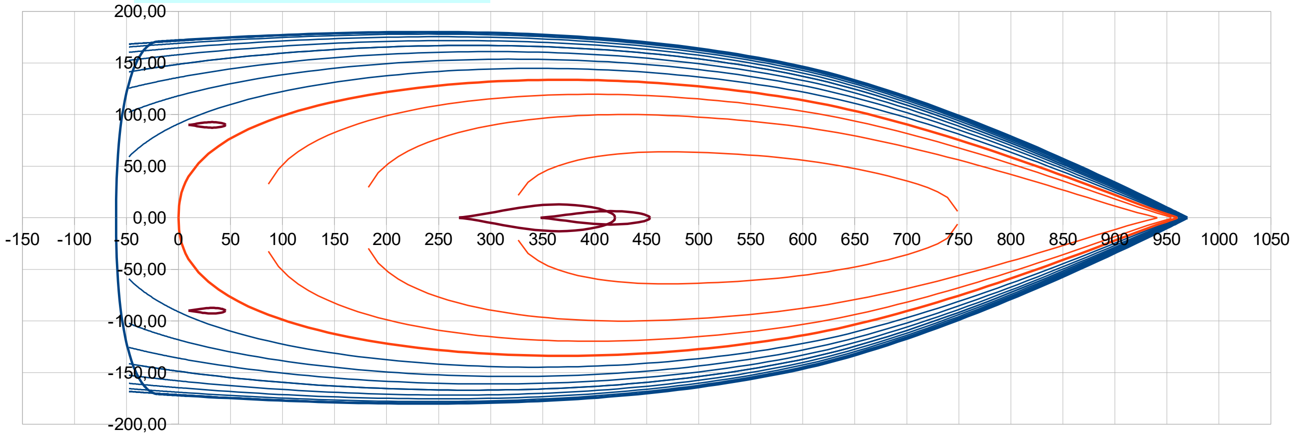
Bg (m)	**1,150**
X Bg (% Lwl)	**65,0**
Alfa (°)	**15,050**
Pui liv y	**1,60**

>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



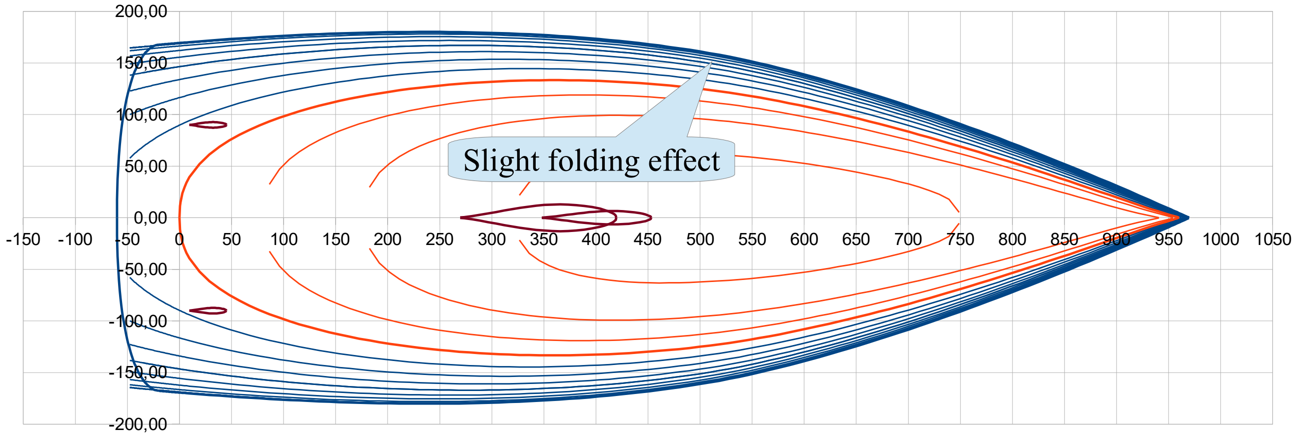
With Pui liv y = 1,8 :

Bg (m)	**0,980**						
X Bg (% Lwl)	**65,0**						
Alfa (°)	**15,050**	**>> Bmax (m)**		**3,60**	**at Xb(%Lwl)**		**25,0**
Pui liv y	**1,80**						



Here, the folding effect is moderated and could be more relevant if we can put it a bit aft, so this variant with X Bg = 55 :

Bg (m)	**1,340**						
X Bg (% Lwl)	**55,0**						
Alfa (°)	**11,450**	**>> Bmax (m)**		**3,60**	**at Xb(%Lwl)**		**25,0**
Pui liv y	**1,80**						



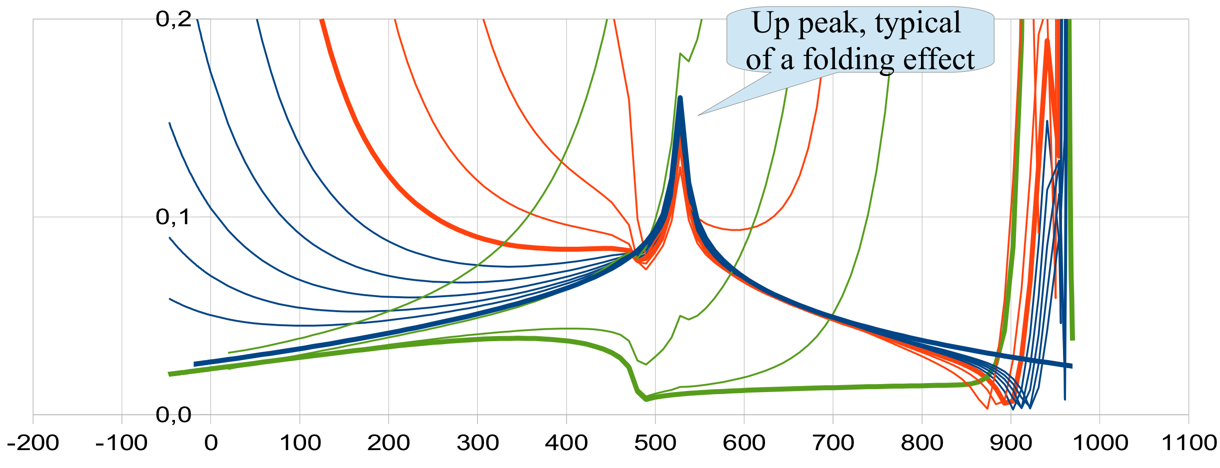
That folding effect, created when Pui liv y < 2, is well showed by the curvature 1/R curve also given in the output, the sheer line 1/R being the thick blue line here below :

Curvatures 1/R :

Red : waterlines below H0 **(thick line = H0)**

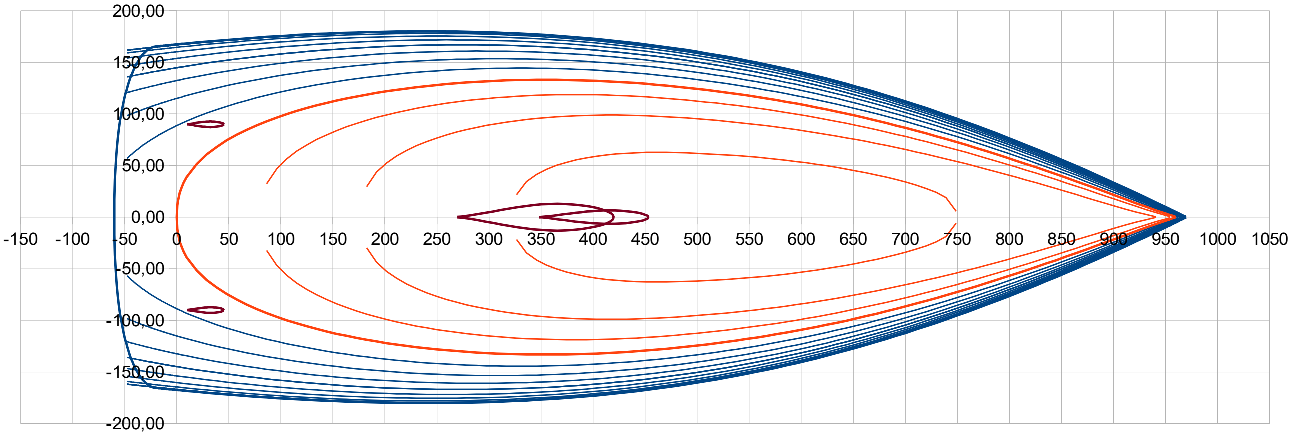
Blue : waterlines above H0 **(thick line = sheer line)**

Green : keel and buttock lines **(Thick line = keel line)**



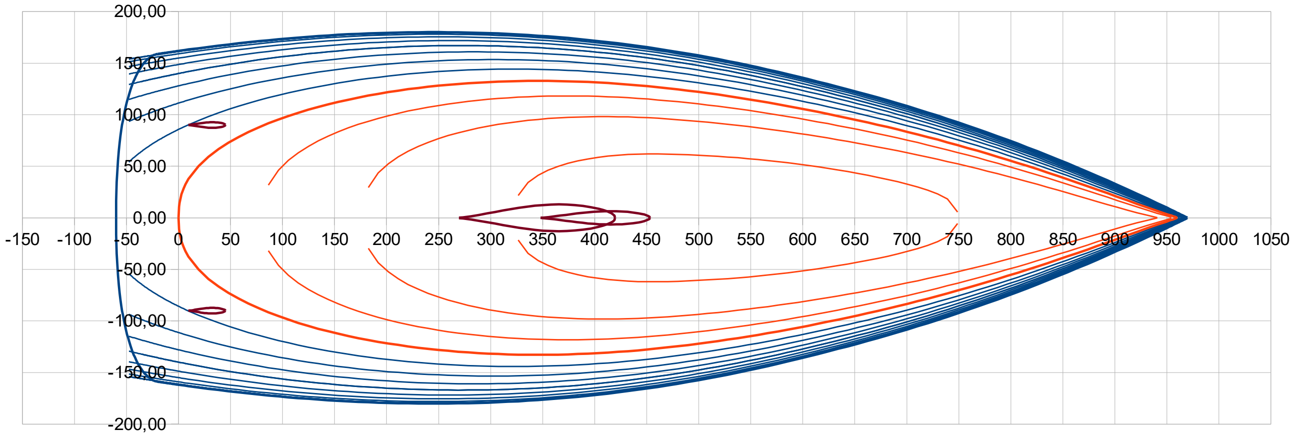
With Pui liv y = 2,0 the recommended value :

Bg (m)	**0,860**				
X Bg (% Lwl)	**65,0**				
Alfa (°)	**15,050**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**25,0**
Pui liv y	**2,00**				



With Pui liv y = 2,2 :

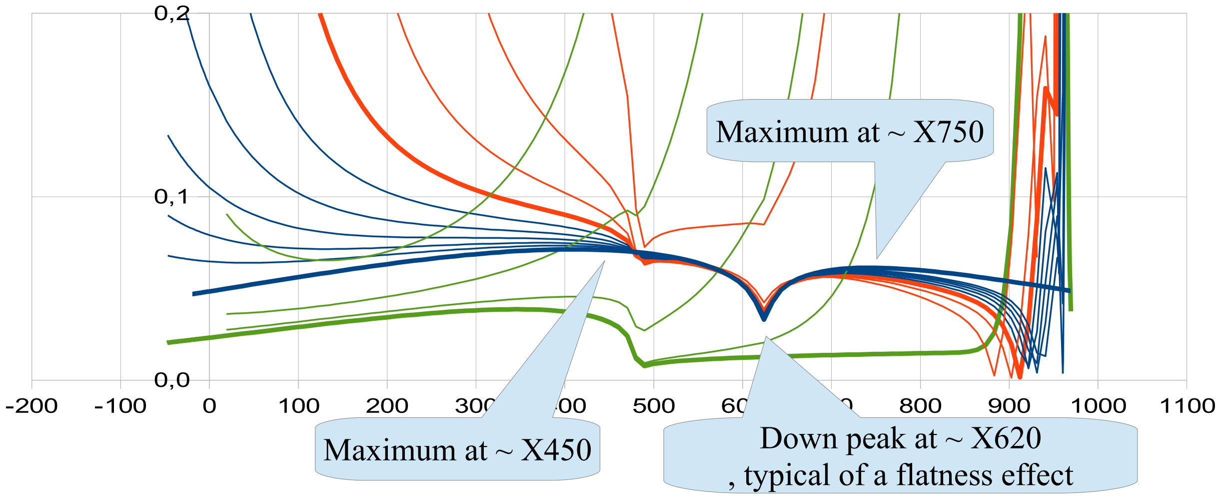
Bg (m)	**0,770**				
X Bg (% Lwl)	**65,0**				
Alfa (°)	**15,050**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**25,0**
Pui liv y	**2,20**				



When Pui liv y > 2 , that creates 2 maxima of the curvature along the sheer line, it is imperceptible on the drawing but well showed by the curvature 1/R curve :

Curvatures 1/R :

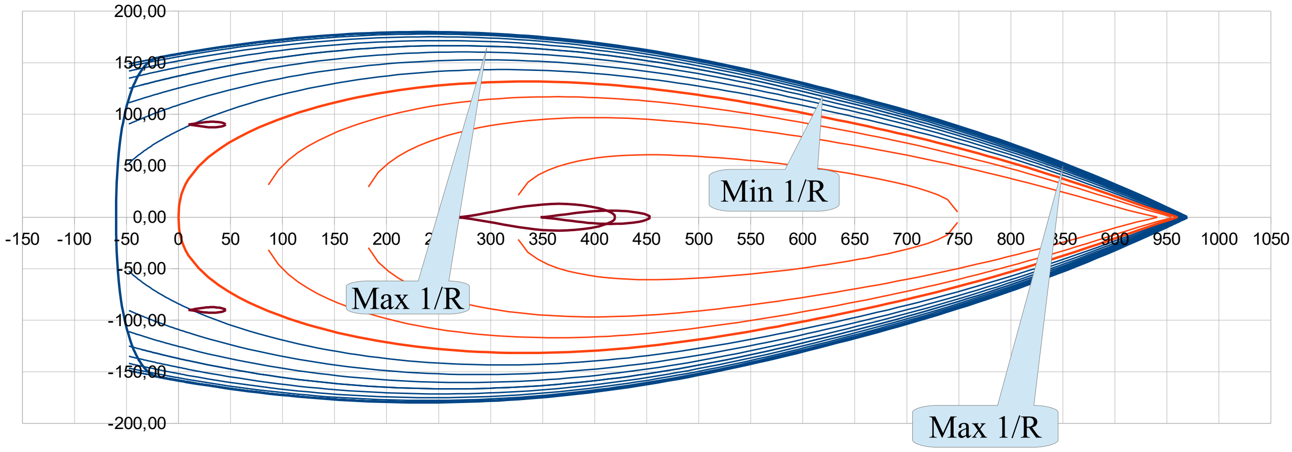
Red : waterlines below H0 **(thick line = H0)**
Blue : waterlines above H0 **(thick line = sheer line)**
Green : keel and buttock lines **(Thick line = keel line)**



With Pui liv y = 2,4 :

Bg (m)	**0,670**
X Bg (% Lwl)	**65,0**
Alfa (°)	**15,000**
Pui liv y	**2,40**

>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



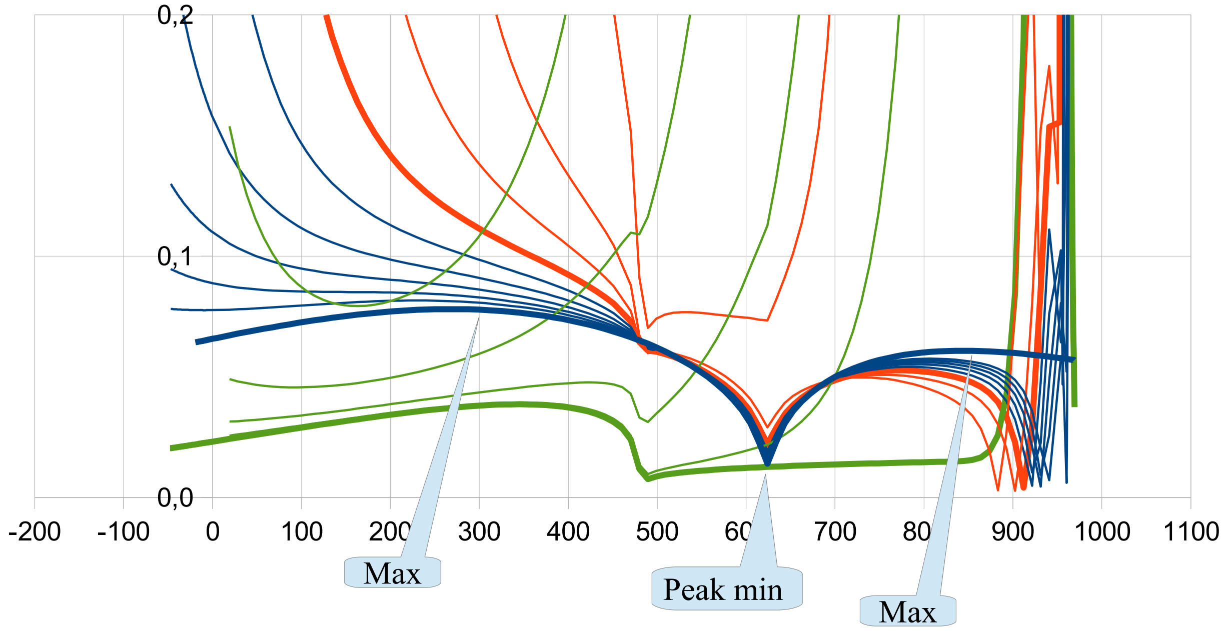
Here the existence of the 2 maxima of curvature is more visible on the sheer line and well showed by the 1/R curve (the blue thick line) :

Curvatures 1/R :

Red : waterlines below H0 **(thick line = H0)**

Blue : waterlines above H0 **(thick line = sheer line)**

Green : keel and buttock lines **(Thick line = keel line)**



After this investigation step, we actually keep the solution with Pui liv y = 2 associated with X Bg = 65, so avoiding either a folding effect (linked to a Pui liv y < 2) or a flatness one (linked to a Pui liv y > 2).

***8* Sheer line adjustment using Cor Pui liv and Pui Cor Pui**

Cor Pui liv recommended values are 0 to 0,04, the effect is to strech the sheer line towards the end, the more Cor Pui liv, the more stretched the line towards the fore and rear ends.

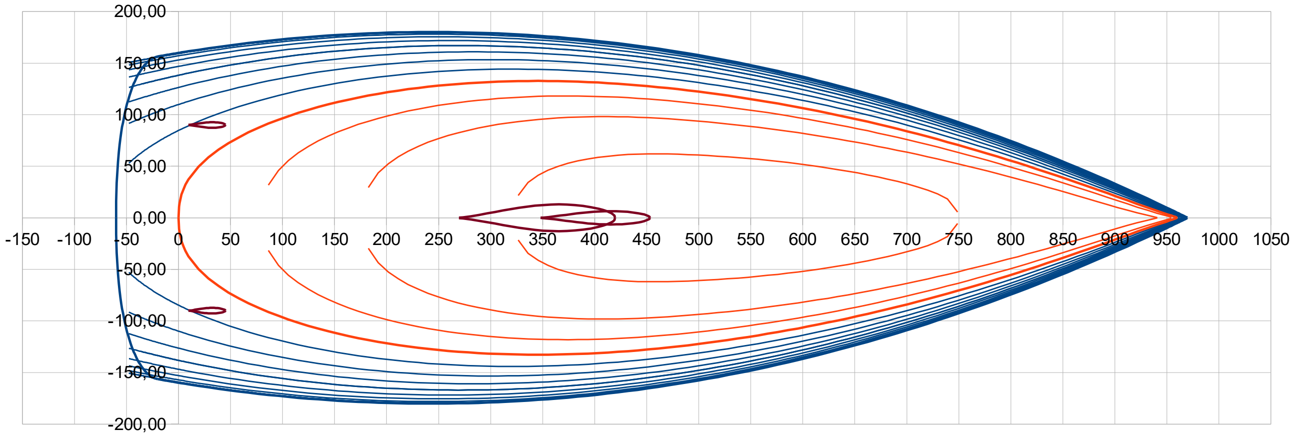
Pui Cor Pui recommended values to test are 0,5 to 2, it is the degree of evolution of Cor Pui liv.

We first test 3 various Cor Pui liv (0, 0,02, 0,04) with Pui Cor Pui = 1 , and of course for each case an adjustement of Bg and alfa to maintain Bmax = 3,60 m and Xb = 25% Lwl.

With Cor Pui liv = 0 :

Bg (m)	0,790
X Bg (% Lwl)	65,0
Alfa (°)	15,050
Pui liv y	2,00
Cor Pui liv	0,000
Pui Cor Pui	1,00

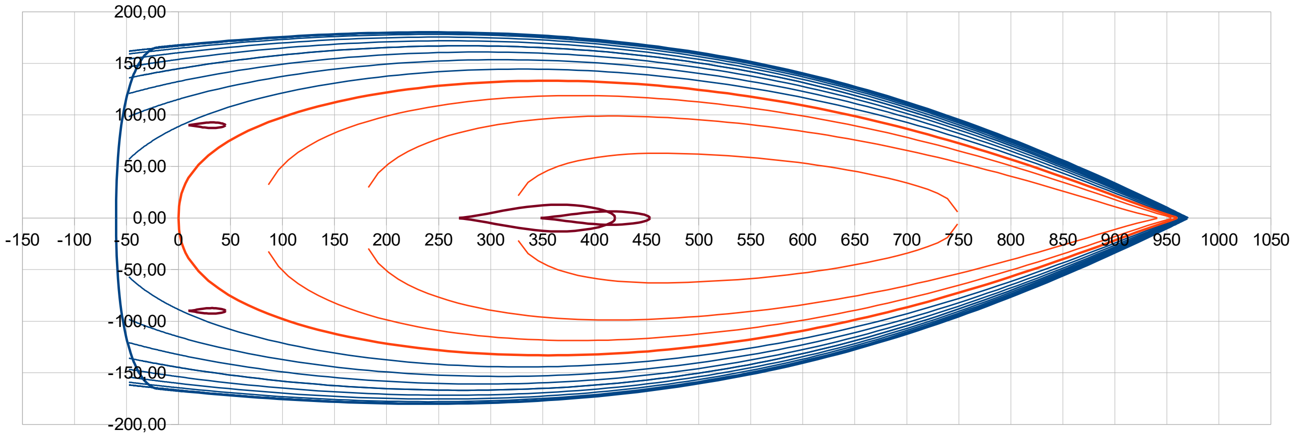
>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



With Cor Pui liv = 0,02 :

Bg (m)	0,860
X Bg (% Lwl)	65,0
Alfa (°)	15,050
Pui liv y	2,00
Cor Pui liv	0,020
Pui Cor Pui	1,00

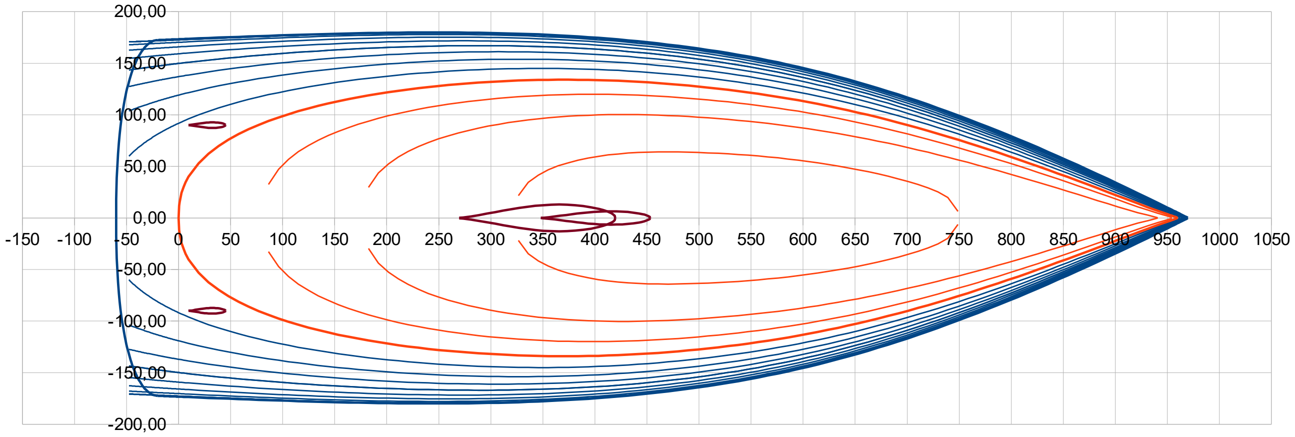
>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



With Cor Pui liv = 0,04 :

Bg (m)	0,960
X Bg (% Lwl)	65,0
Alfa (°)	15,050
Pui liv y	2,00
Cor Pui liv	0,040
Pui Cor Pui	1,00

>> Bmax (m) 3,60 at Xb(%Lwl) 25,0

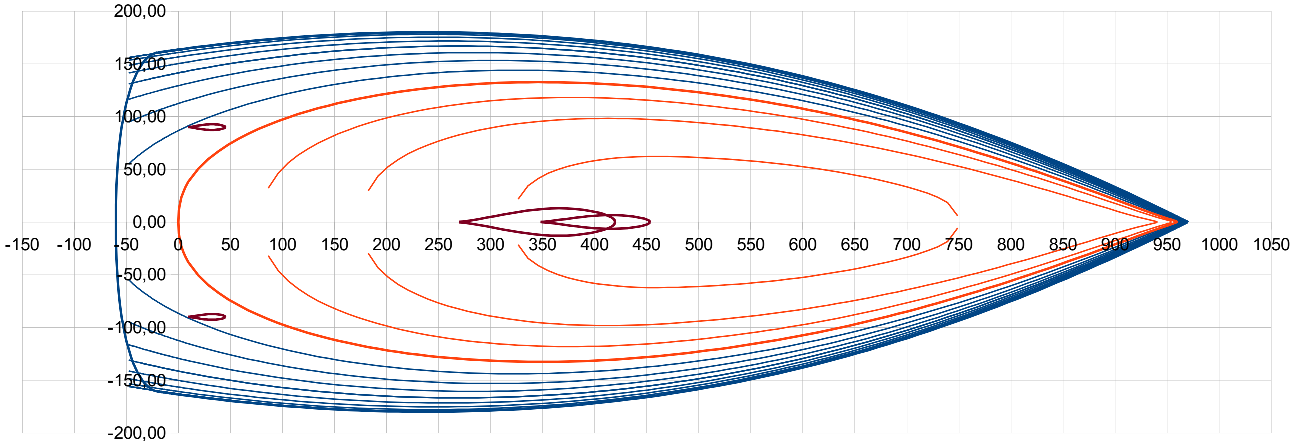


0 leads to more a more rounded line, 0,04 leads to more stretched line ends. One can keep Cor Pui liv = 0,02 as a good average value. Now, let's test the influence of Pui Cor Pui with 0,5 or with 1,50

With Pui Cor Pui = 0,5 :

Bg (m)	0,820
X Bg (% Lwl)	65,0
Alfa (°)	15,030
Pui liv y	2,00
Cor Pui liv	0,020
Pui Cor Pui	0,50

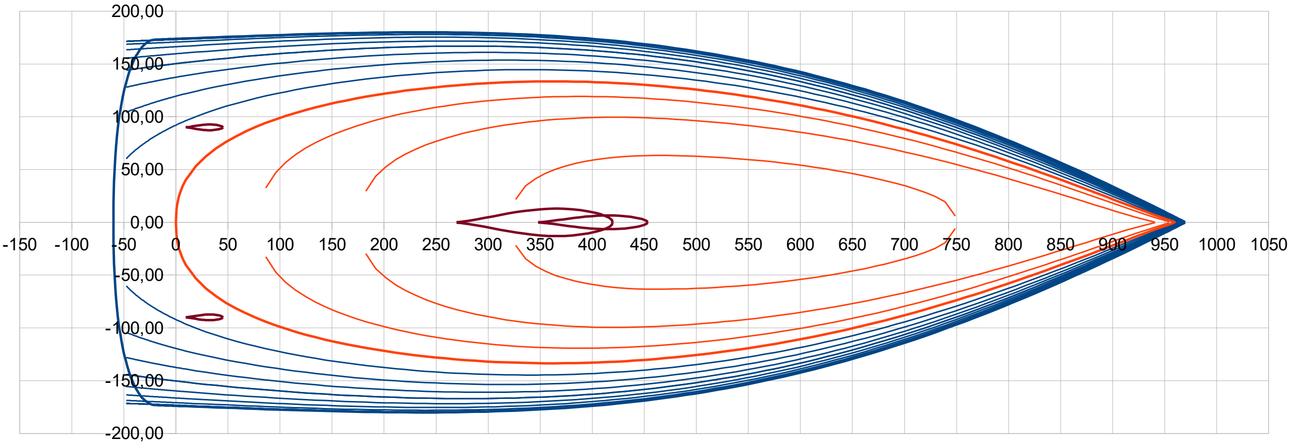
>> Bmax (m) 3,60 at Xb(%Lwl) 25,0



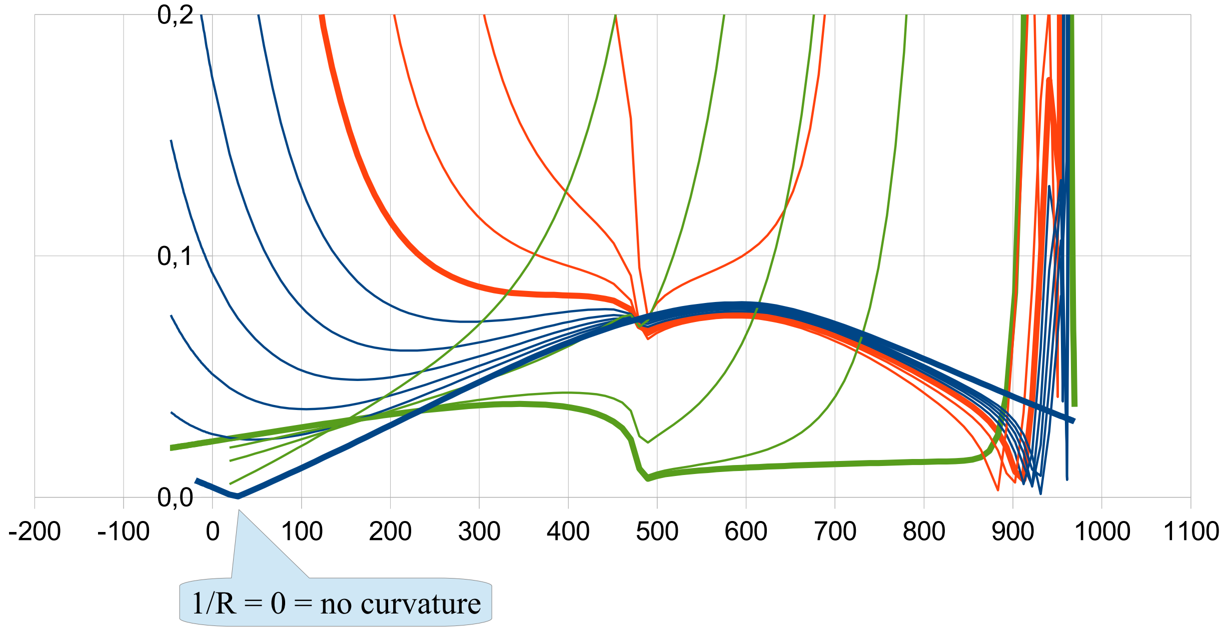
With Pui Cor Pui = 1,5 :

Bg (m)	0,900
X Bg (% Lwl)	65,0
Alfa (°)	15,050
Pui liv y	2,00
Cor Pui liv	0,020
Pui Cor Pui	1,50

>> Bmax (m) 3,60 at Xb(%Lwl) 25,0

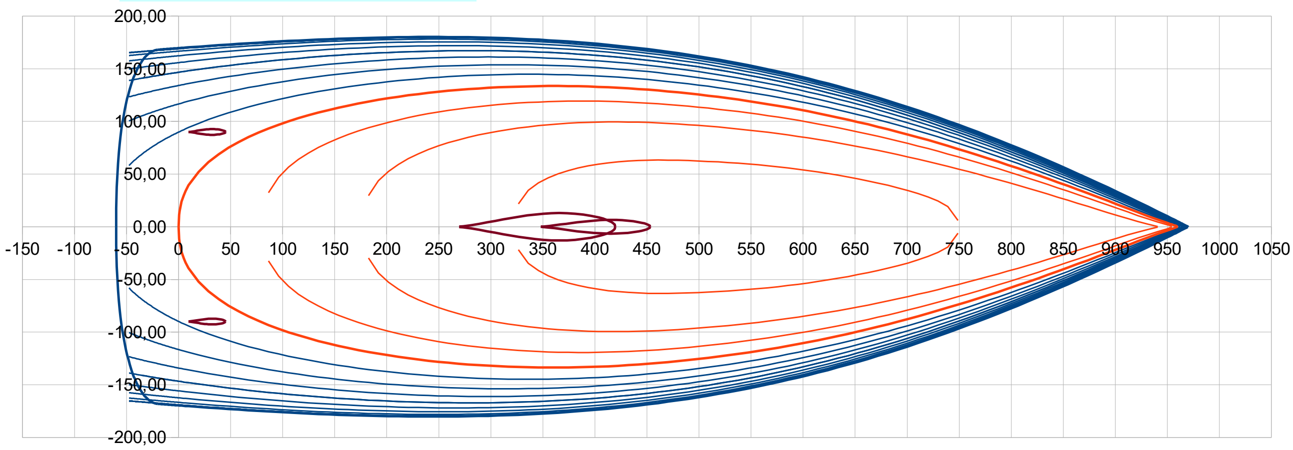


One can see from the curvature 1/R curve that the rear end of the sheer line is flat (even with a slight inflexion point) :

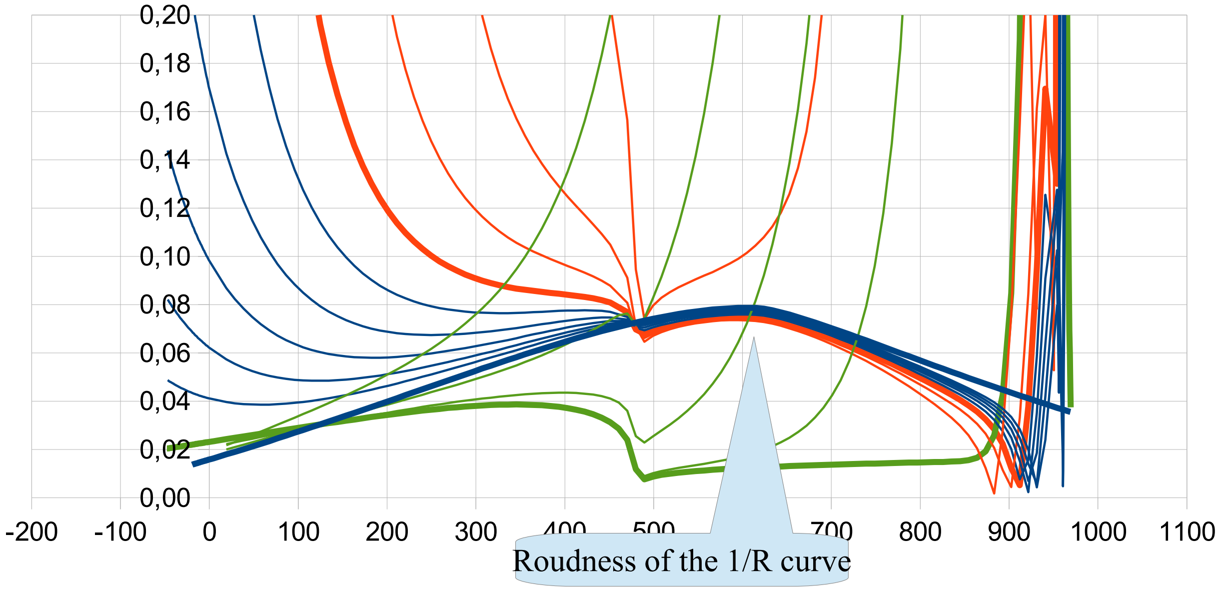


One can consider that more stretched rear end of the sheer line is good but not as much as above, so let's consider an average value between 1 and 1,5 , so 1,25 :

Bg (m)	**0,890**				
X Bg (% Lwl)	**65,0**				
Alfa (°)	**15,070**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**25,0**
Pui liv y	**2,00**				
Cor Pui liv	**0,020**				
Pui Cor Pui	**1,25**				



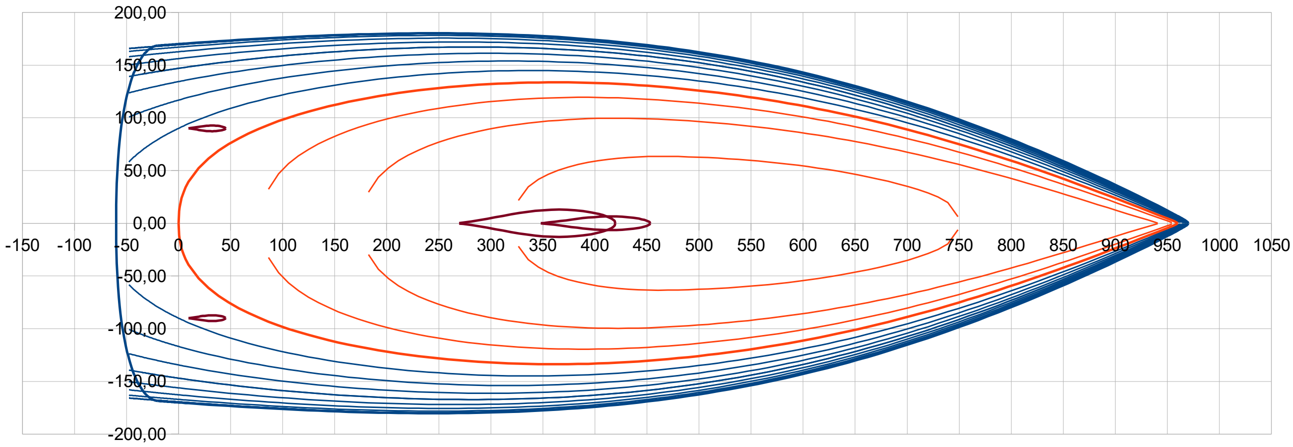
To take Pui Cor Pui > 1 has moreover the advantage to soft the curvature 1/R evolution in the midship zone (no peak as with Pui Cor Pui = 1 or under) :



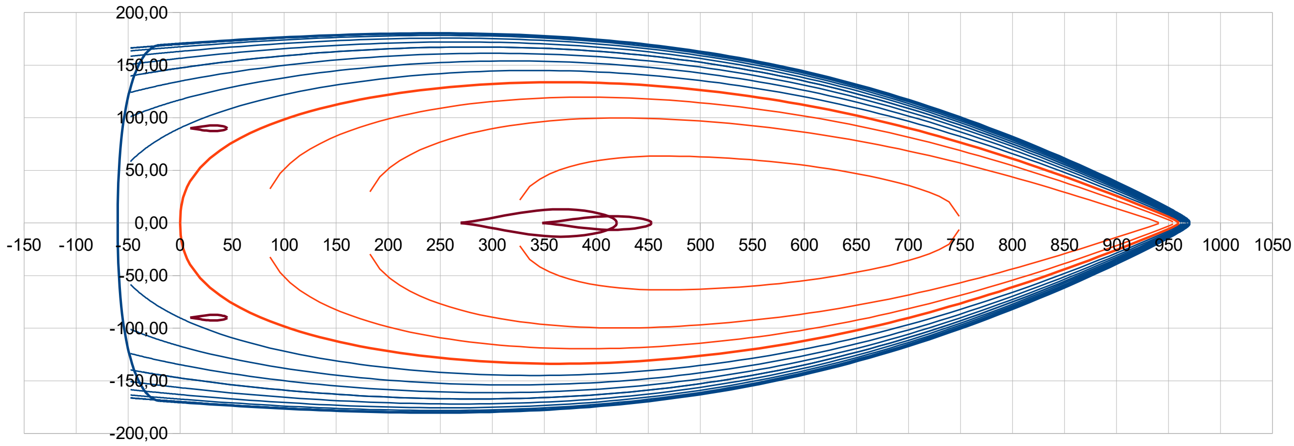
***9* Sheer line adjustment using Scow**

It is the last point to adjust the sheer line. The « Scow » parameter can introduce roundness at the very fore end of the line : a small value of Scow (< 0,1) just put the roudness which is anyway necessary to build the bow, a greater value of Scow can lead to a real scow bow version of the boat. Here we will explore small values of Scow, let'say 0,03, 0,06, 0,09 + a high value (0,4) just to show what can be a scow bow version although it is not the objective :

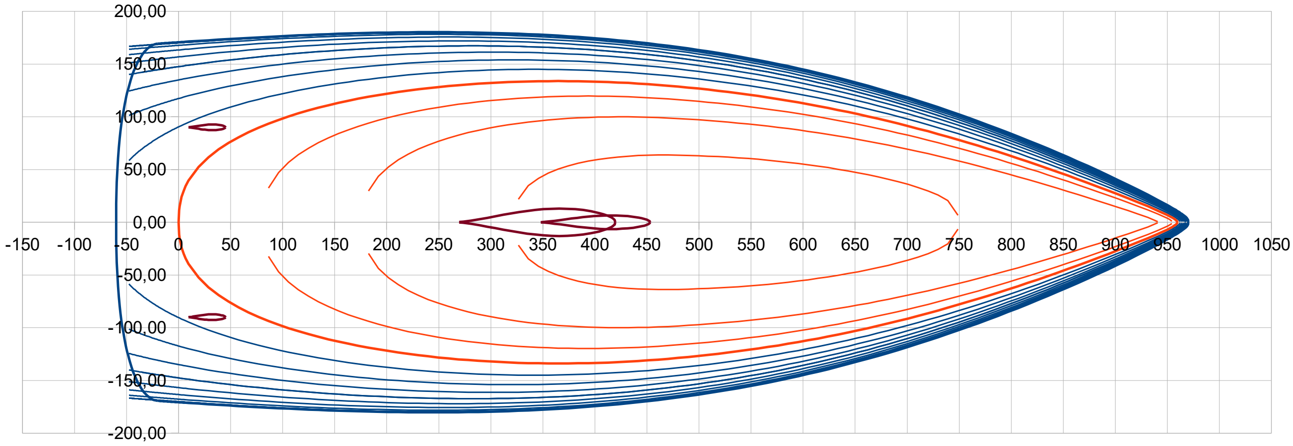
With Scow = 0,03 :



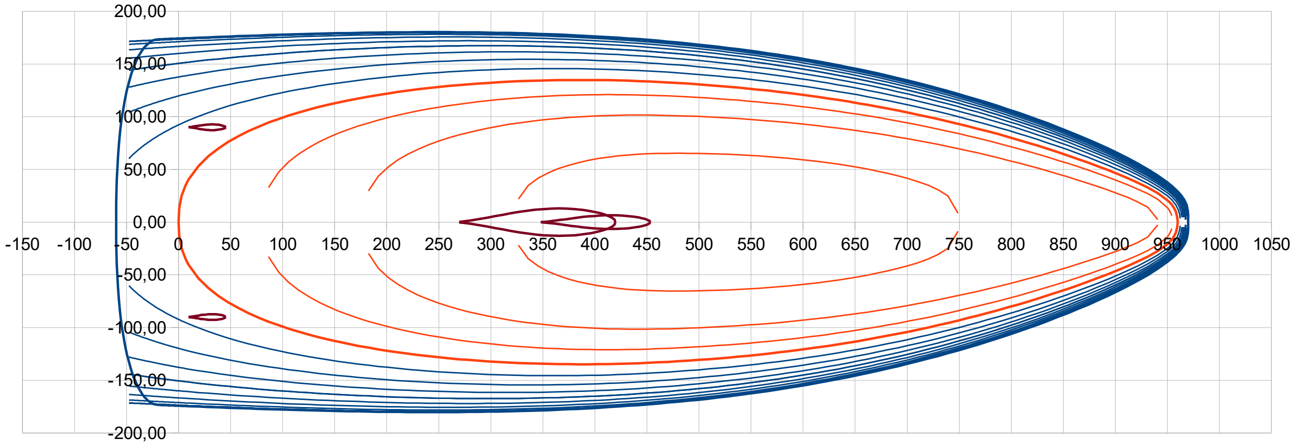
With Scow = 0,06 :



With Scow = 0,09 :

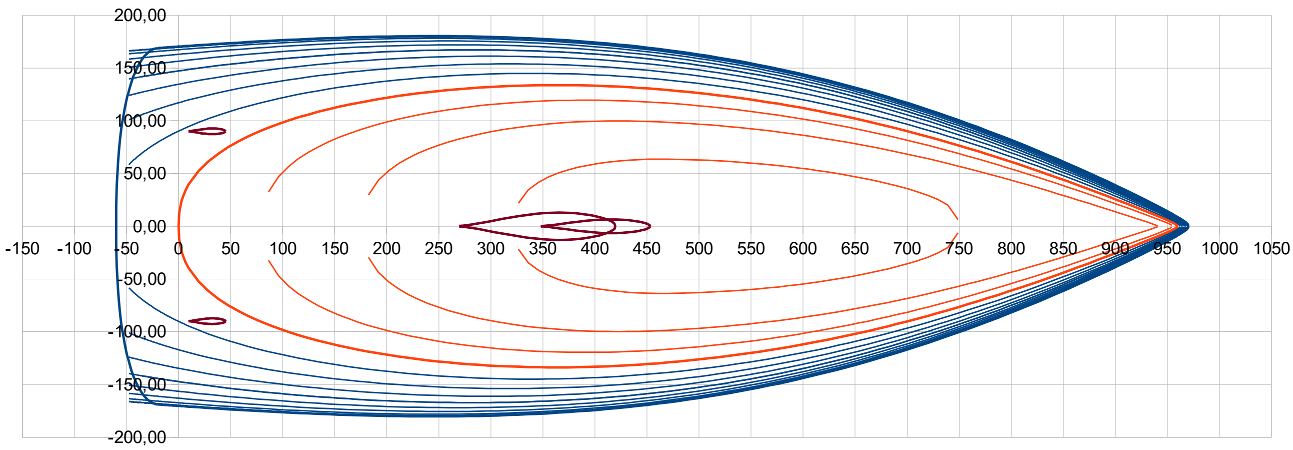


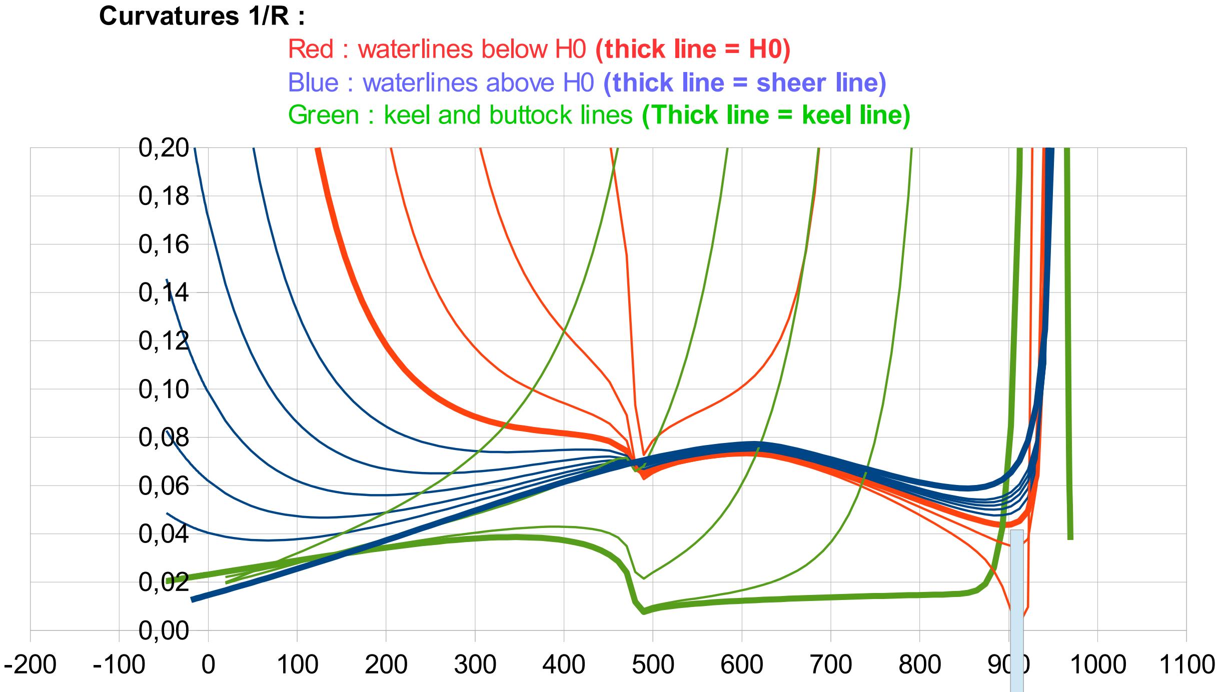
With Scow 0,4 :

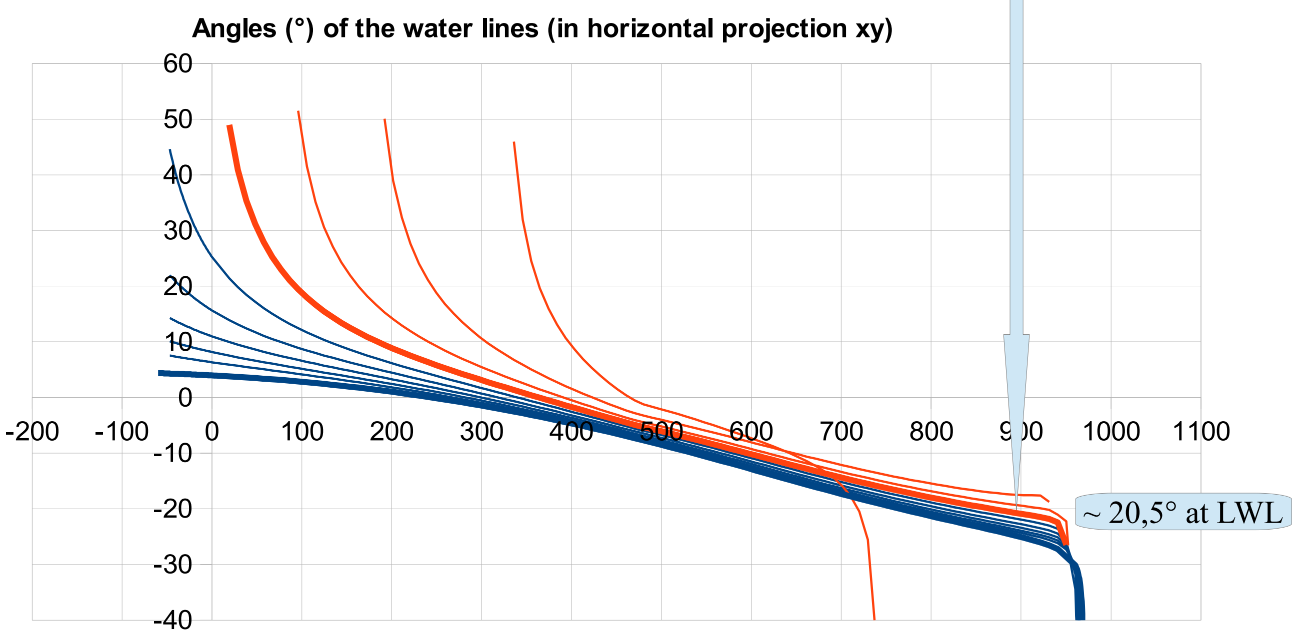


At this stage, one can consider that with « Scow » = 0,06 we have the requested small roudness at the bow very end, representative of the real building of the hull. Summarize of the sheer line data finally adopted and a first evaluation of the entry half-angle of the waterline (angles are also given in the output) :

Bg (m)	**0,890**						
X Bg (% Lwl)	**65,0**						
Alfa (°)	**15,070**	**>> Bmax (m)**	**3,60**	**at Xb(%Lwl)**	**25,0**		
Pui liv y	**2,00**						
Cor Pui liv	**0,020**						
Pui Cor Pui	**1,25**						
X liv ar (m)	**-0,20**						
Scow	**0,06**						







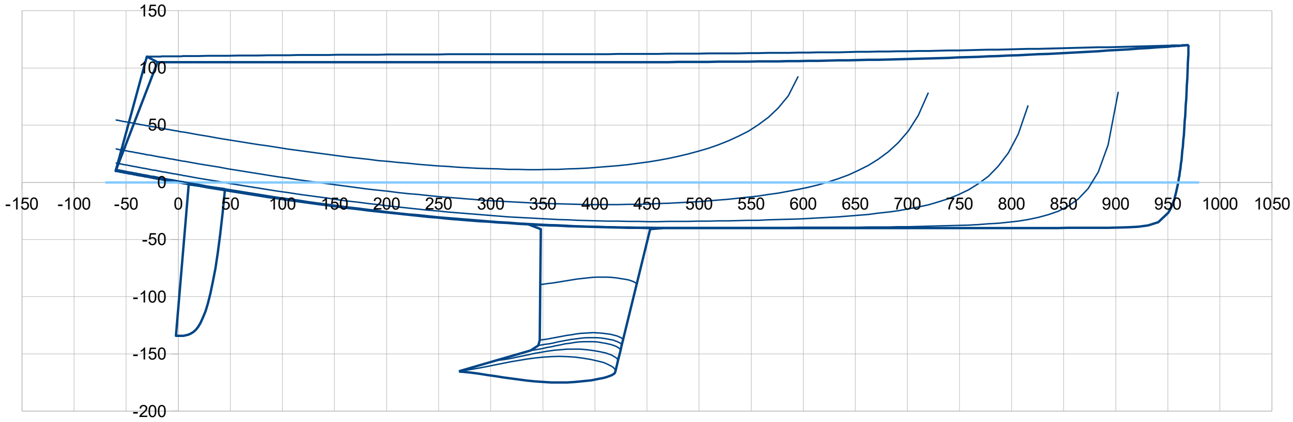
>>> One can evaluate the entry half-angle at the X position where the curvature is minimum before increasing sharply at very fore end due to the roudness : this angle is ~ 20,5° for the LWL, which is within the usual ones for cruising yachts.

Ted Brewer recommendation, from « Understanding Boat design » :
« Half angle of entrance : the angle, measured at the LWL, between the hull centerline and the actual waterline shape. Fine angles are desirable for good performance but can be overdone, creating a wet boat in a seaway. Angles below 19-20 degrees would be considered fine, 20-24 degrees is fairly usual for a cruising yacht and angles of 25 degrees and above are considered bluff bows today but were fairly common in the '60s. »

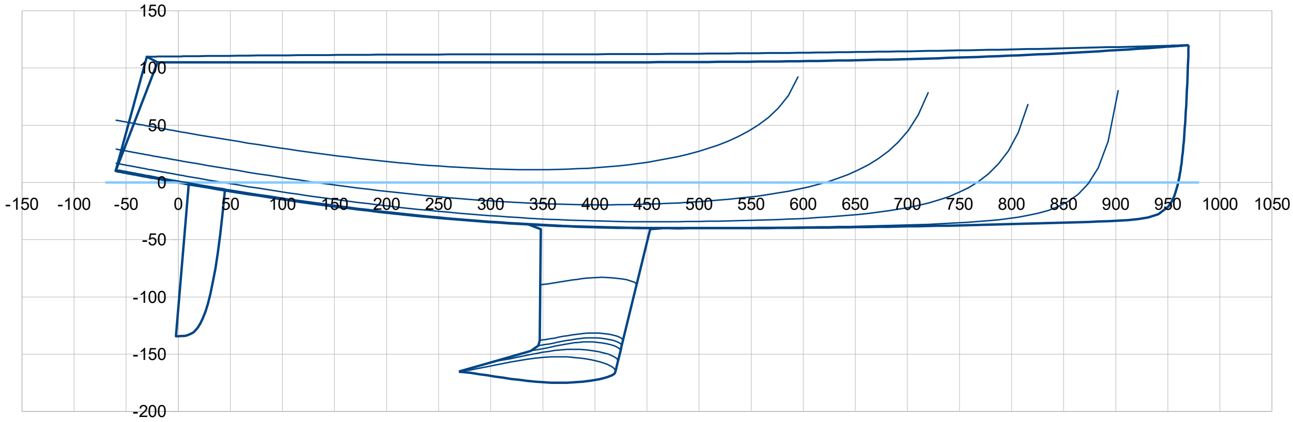
***10* Keel line fore part adjustement, using the adimensional parameter Cet**

Fore part means where X > X Tc . At first, let's test various Cet to see its influence :

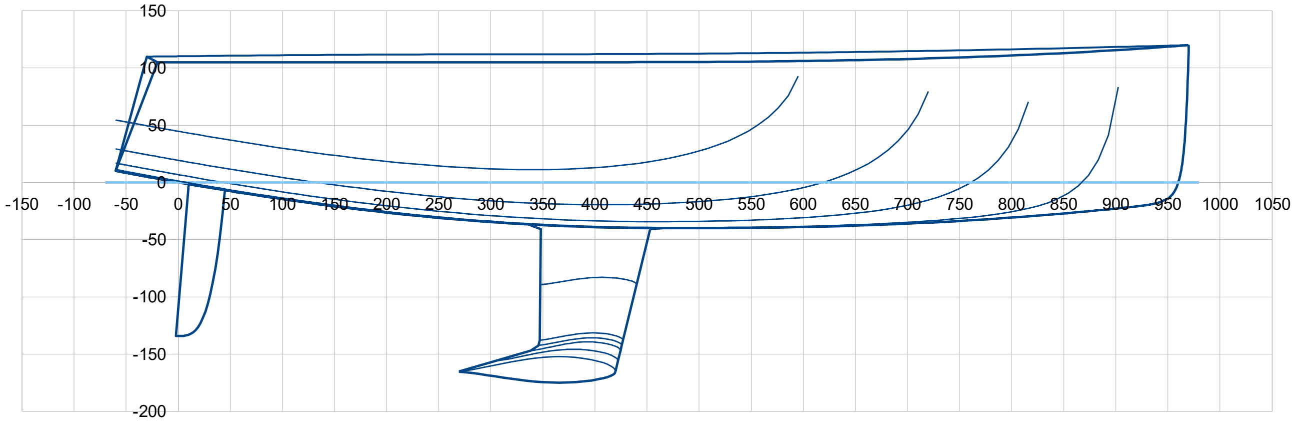
Cet	10



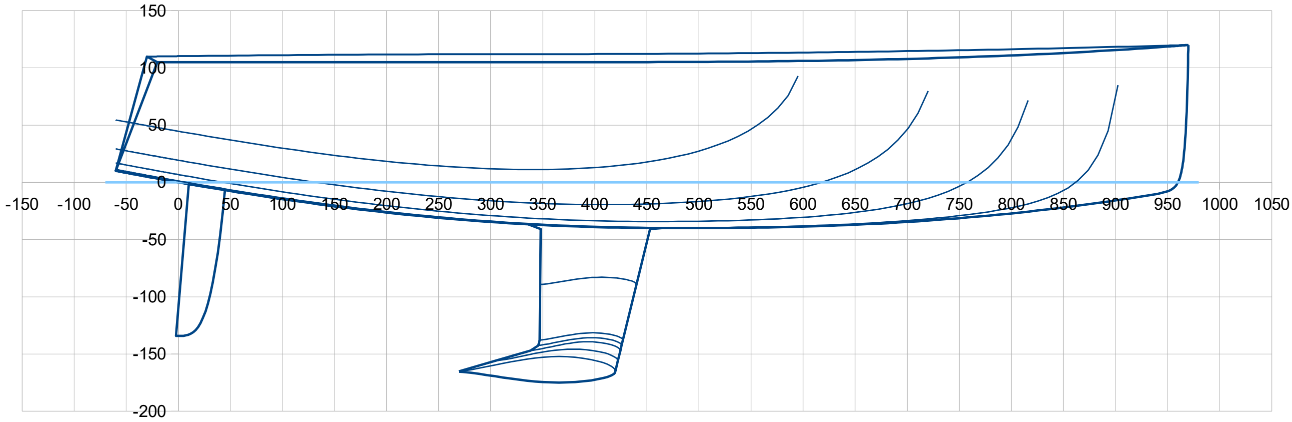
Cet	30



Cet	60



Cet	100



>>> At this stage, ***one can select Cet = 60***

11 Hull draft adjustement for the displacement objective

At that step , one can to have a first check on the total displacement in the hydrostatics output data before going further :

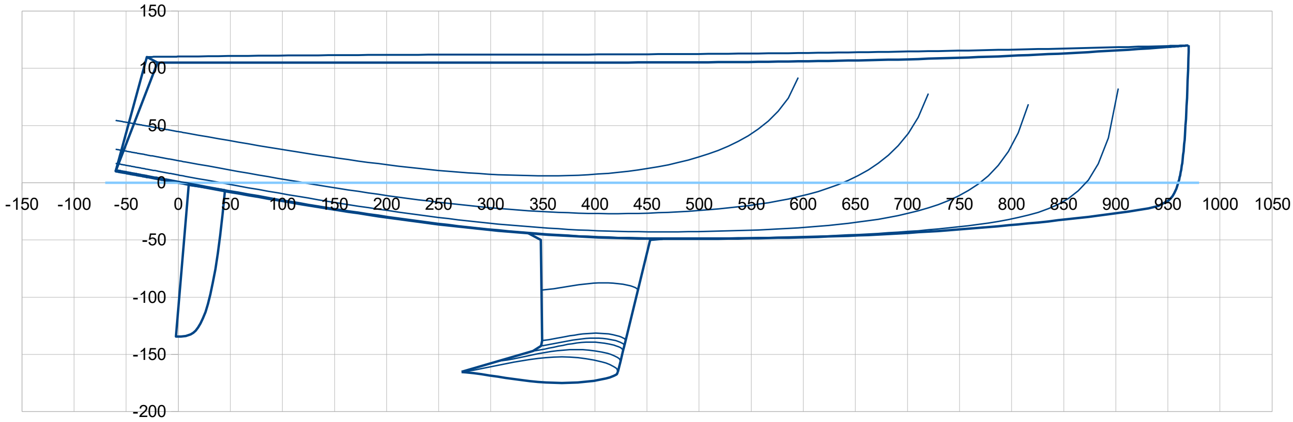
Displacement at H0 (m3)	**4,65230**
(kg)	**4769**

, quite lighter than the expected objective 5950 kg >>> we will increase the hull draft Tc (presently 0,4 m) up to have a heavier displacement equal or close to the objective :

Tc (m)	**0,500**		
		Displacement at H0 (m3)	**5,90286**
		(kg)	**6050**

Tc (m)	**0,490**		
		Displacement at H0 (m3)	**5,77704**
		(kg)	**5921**

Let's adopt 0,49 m and look again to the keel line :



12 Keel and ballast preliminary adjustment

For this preliminary adjustement involving all the geometrical parameters of the keel, one have to look at 2 ouput values in the hydrostatics : the total ballast which should be close to the objective 2100 kg, the CLR (Center of Lateral Resistance) to be put preliminary at around 53% Lwl (it is not a criteria, just an indication for a first positioning, the criteria will be the Lead). And of course the draft is to put at the objective 1,95 m.

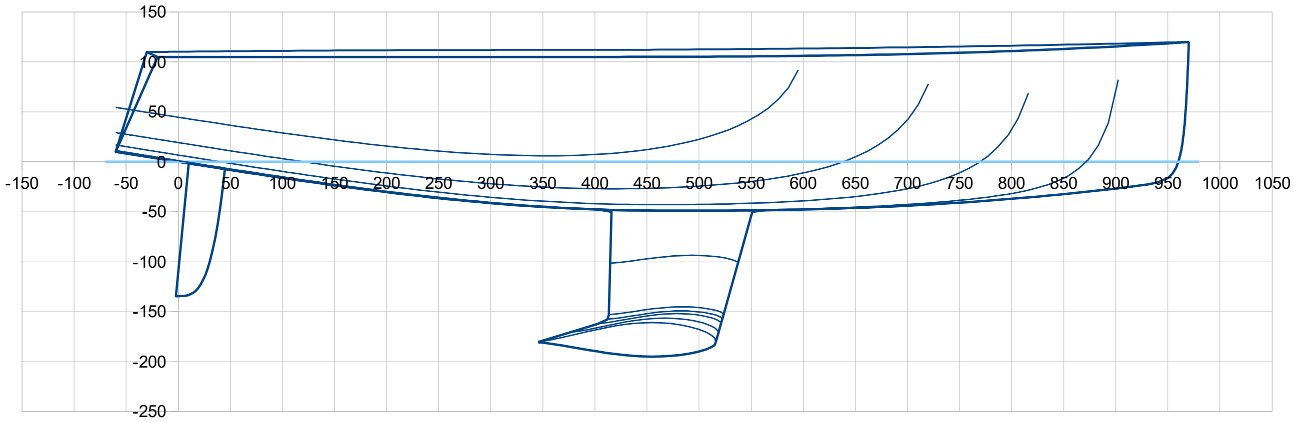
Initial values >>>>> New values to input

1.2 Keel data			
Xq ar (m)	**3,48**	**4,16**	Rear point of the root chord
C root (m)	**1,05**	**1,35**	Root chord length
C tip (m)	**0,80**	**1,10**	Tip chord lenght (before the bulb protuberence)
Th keel(cm)	**13,00**	**16,00**	Max thickness of the keel
F angle (°)	**75,00**	**75,00**	Keel front angle, should be 45° to 90°
C bulb (m)	**1,54**	**1,75**	Bulb chord
Th bulb(cm)	**26,00**	**39,00**	Max thickness of the bulb
Draft oa (m)	**1,75**	**1,95**	should be > hull draft Tc
naca 00xx	**0**	**0**	Type of profile (in the horizontal plans)
naca 63-0xx	**1**	**1**	**Put 1 for the profile used, 0 for the others**
naca 65-0xx	**0**	**0**	
Density keel	**7,30**	**7,30**	Font 7,3 ; Steel : 7, 85 ; Lead 11,35 ; …
Density bulb	**7,30**	**11,35**	

initial output **>>>> giving with the new values**

Ballast (kg)	**875**	**Ballast (kg)**	**2110**	
CLR (%Lwl)	**43,86**	**CLR (%Lwl)**	**52,94**	*CLR = Center of Lateral Resistance*

method : keel profile extended to the waterline, CLR at 25% chord and 45% draft oa

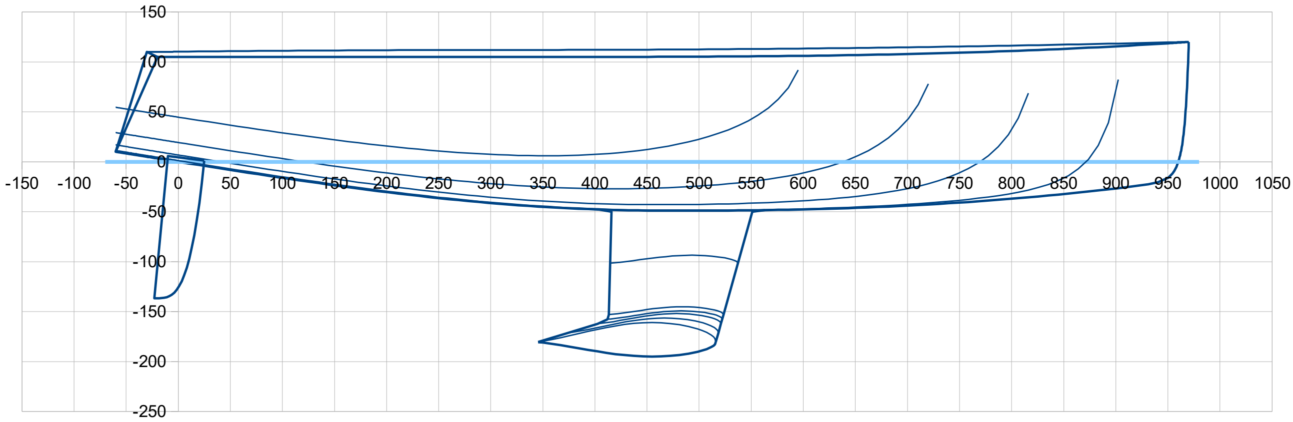


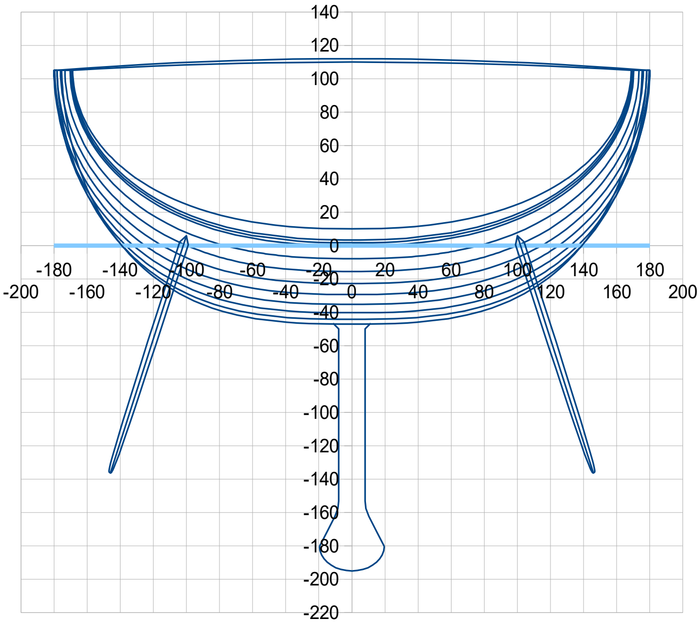
13 Rudders preliminary adjustment

At first, just to position them a bit more aft (to change Xr ar), a bit further apart (to change Offset), a bit more deeper (to increase L ar). The rudders aera will be adjusted later on, in relation with the sailplan pre designed.

Initial values **>>>>>** **New values to input**

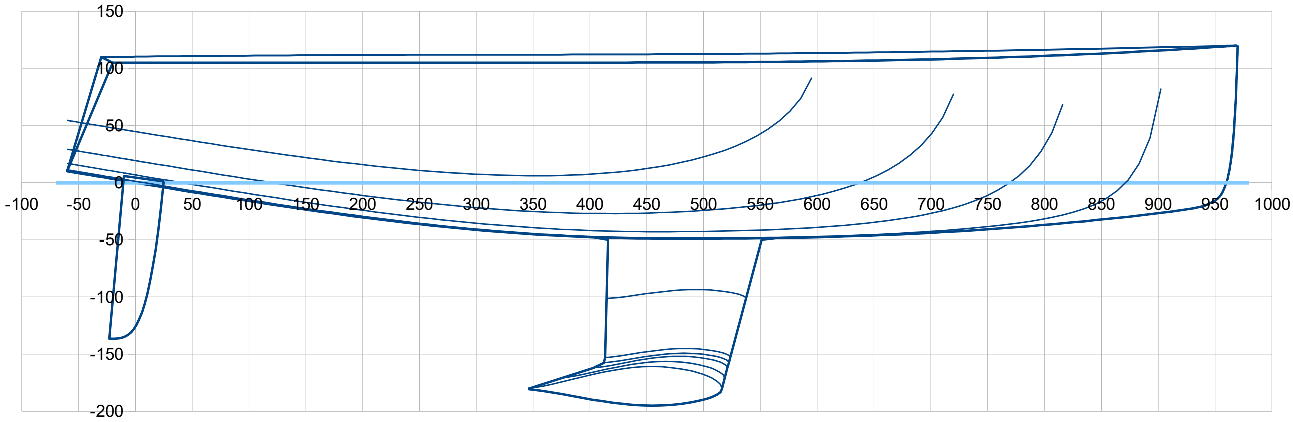
1.3 Rudder data			
Xr ar (m)	**0,10**	**-0,10**	Rear point of the root chord
C root (m)	**0,35**	**0,35**	Root chord length
t/c (%)	**15,00**	**15,00**	Relative thickness of the profile
R angle (°)	**85,00**	**85,00**	Rudder rear angle, should be around 80°-85°
L ar (m)	**1,40**	**1,50**	Rudder rear span
C roundness	**3,50**	**3,50**	Roudness of the profile lower part ; should be usually 2,5 to 5,5
naca 00xx	**0**	**0**	Type of profile (in the horizontal plans)
naca 63-0xx	**1**	**1**	**Put 1 for the profile used, 0 for the others**
naca 65-0xx	**0**	**0**	
Nb of rudders	**2**	**2**	1 or 2 rudders
Offset y (m)	**0,90**	**1,00**	Put 0 when 1 rudder ; offset 'y' when 2 rudders
Angle (°)	**18,0**	**18,0**	'put 0 when 1 rudder ; Angle of the rudder with vertical when 2 rudders

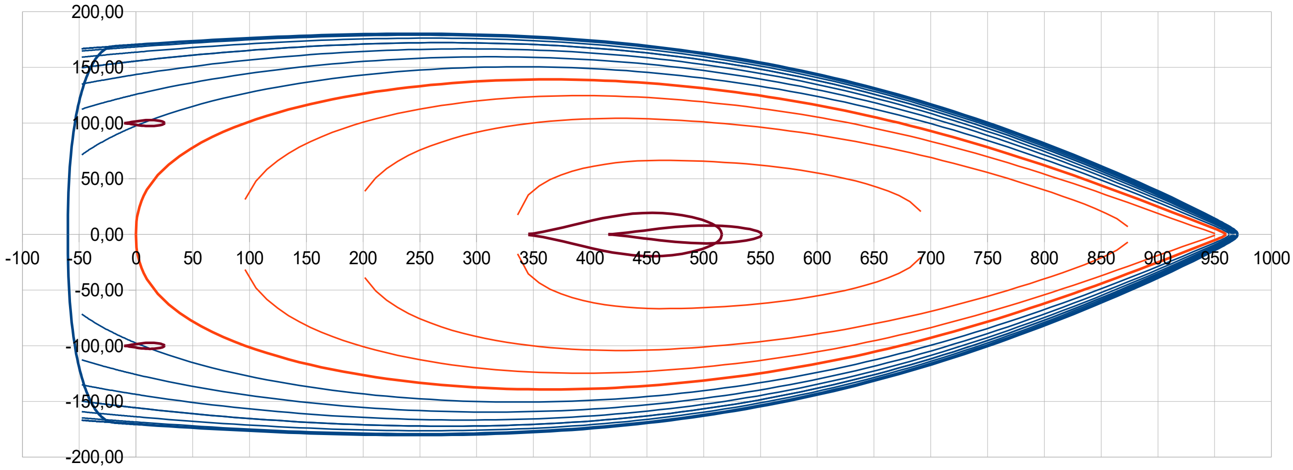


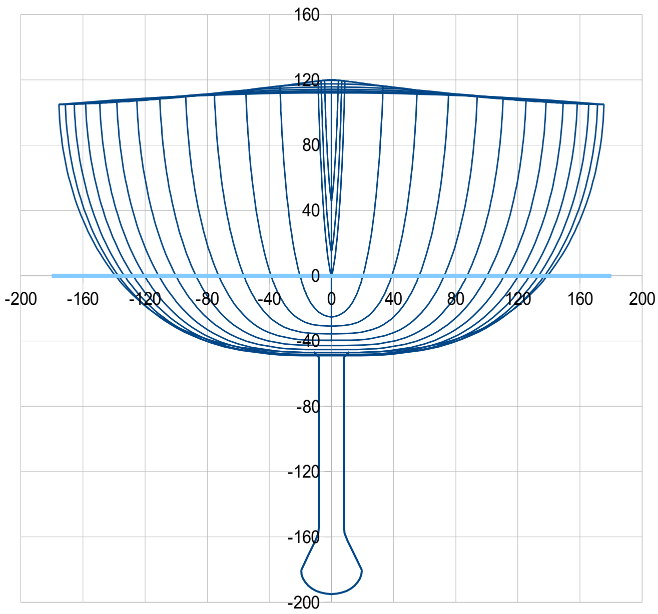


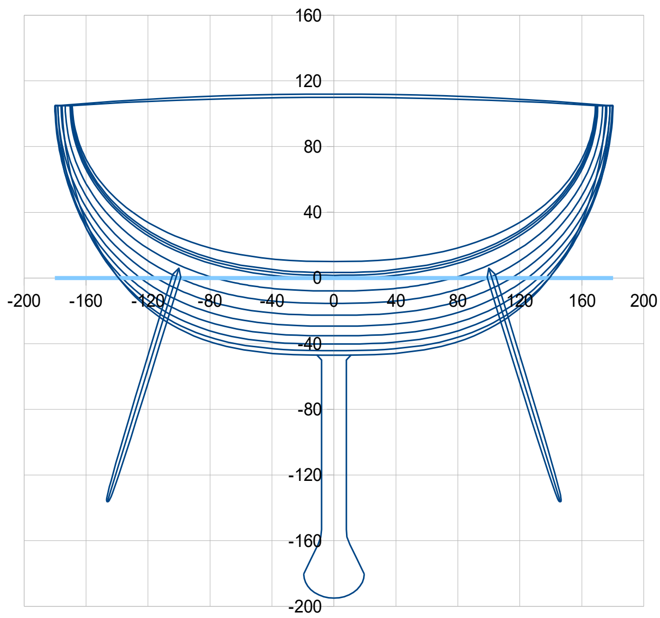
14 Adjustment of the 2D views grids and axis size

Now that the size of the boat and its appendages are defined, we can adjust the 2D views, through axis X and axis Y format functions, for an optimal vision.







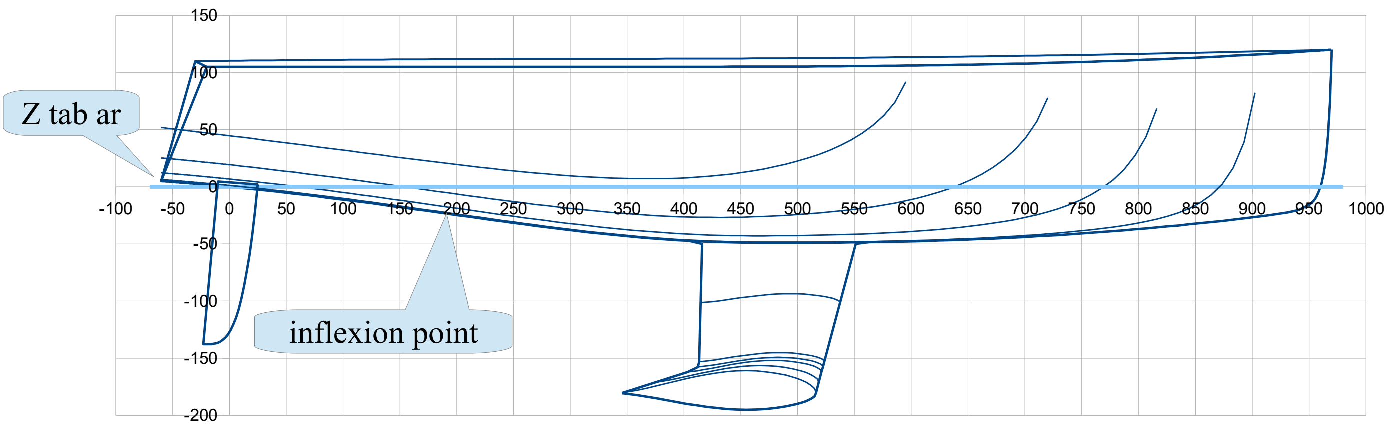


***15* Keel line aft part adjustment, using the height of the rear end of the transom Z tab ar**

We will show that this geometrical data has an influence on the whole shape of the keel line rear part, and so on the displacement, the LCB, the Cp and also on the more or less stretching of the buttock lines. The present value is 0,1, let's test various values from 0,05 to 0,25.

With Z tab ar (m) = 0,05 :

Z tab ar (m) **0,050**



\>>> from the hydrostatics output :

Displacement at H0 (kg)	**5702**	**Xc (%Lwl)**	**50,40**	**Cp (%)**	**54,23**

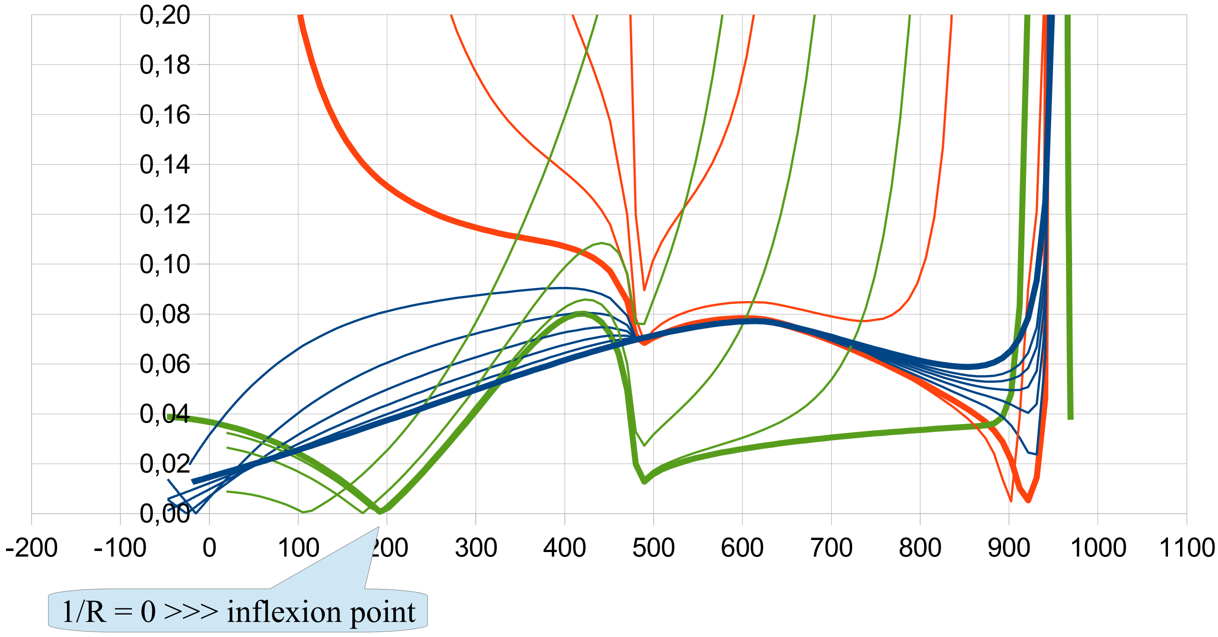
>>> from the 1/R curve :

Curvatures 1/R :

Red : waterlines below H0 **(thick line = H0)**

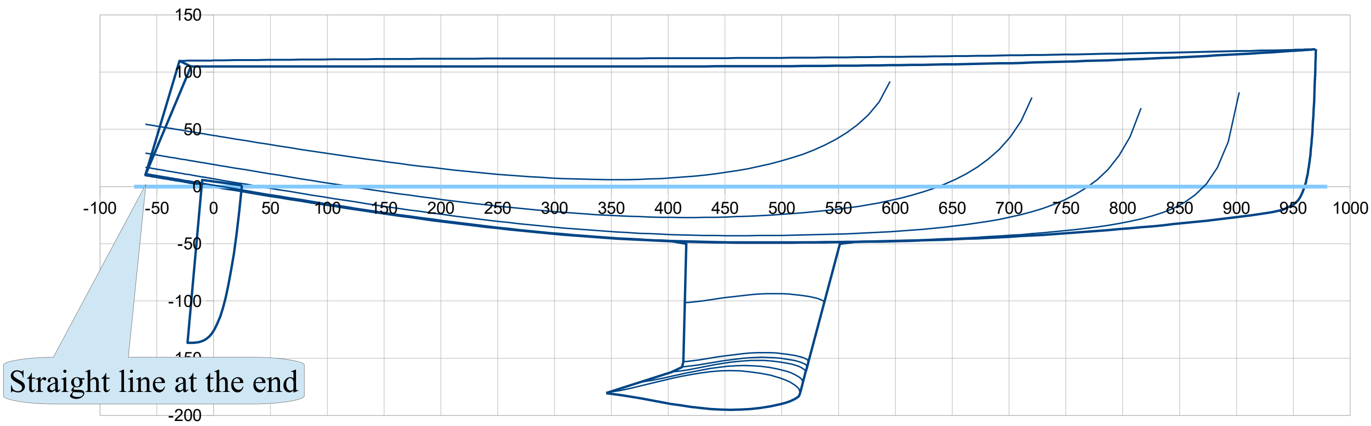
Blue : waterlines above H0 **(thick line = sheer line)**

Green : keel and buttock lines **(Thick line = keel line)**



With Z tab ar (m) = 0,1 :

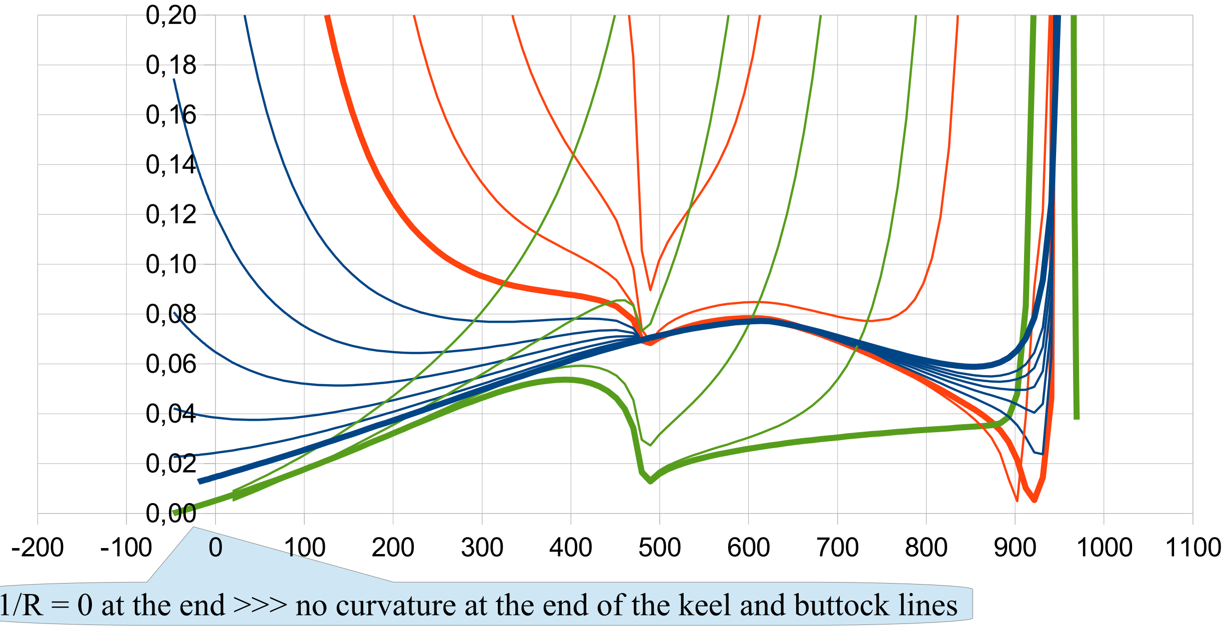
Z tab ar (m)	0,100



>>> from the hydrostatics output :

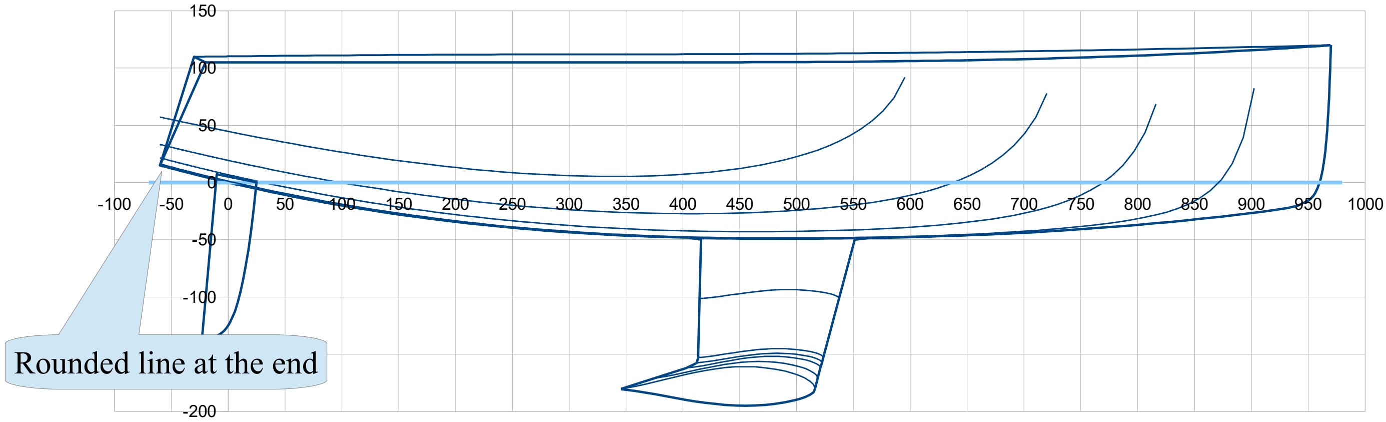
Displacement at H0 (kg)	6039	Xc (%Lwl)	48,71	Cp (%)	57,30

>>> from the 1/R curve :



With Z tab ar (m) = 0,15 :

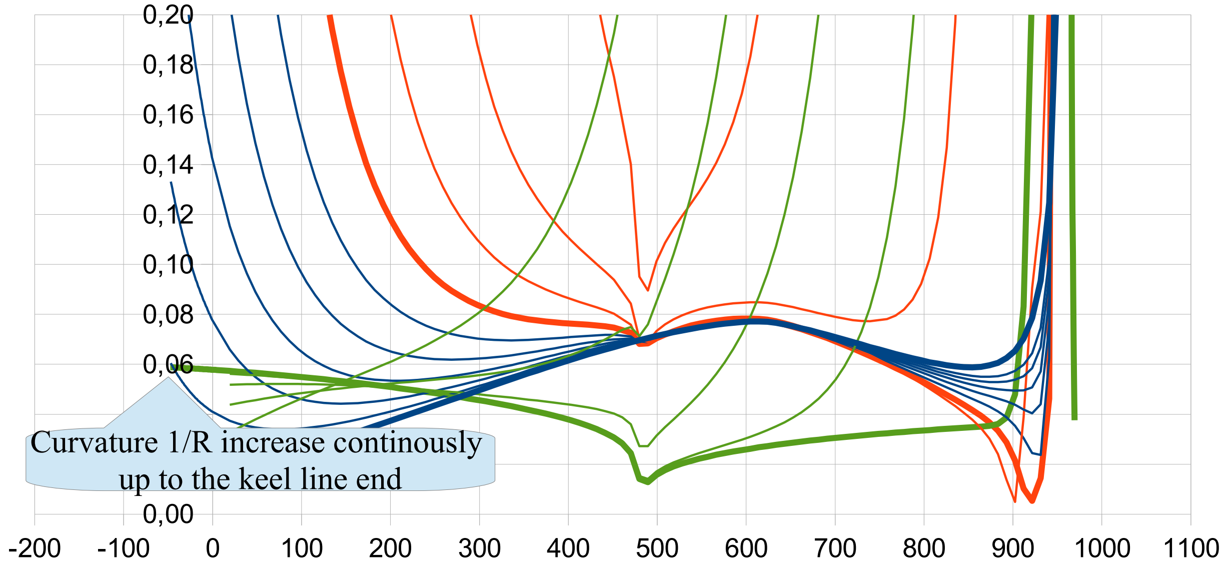
Z tab ar (m)	**0,150**



>>> from the hydrostatics output :

Displacement at H0 (kg)	**6293**	**Xc (%Lwl)**	**47,51**	**Cp (%)**	**59,63**

>>> from the 1/R curve :

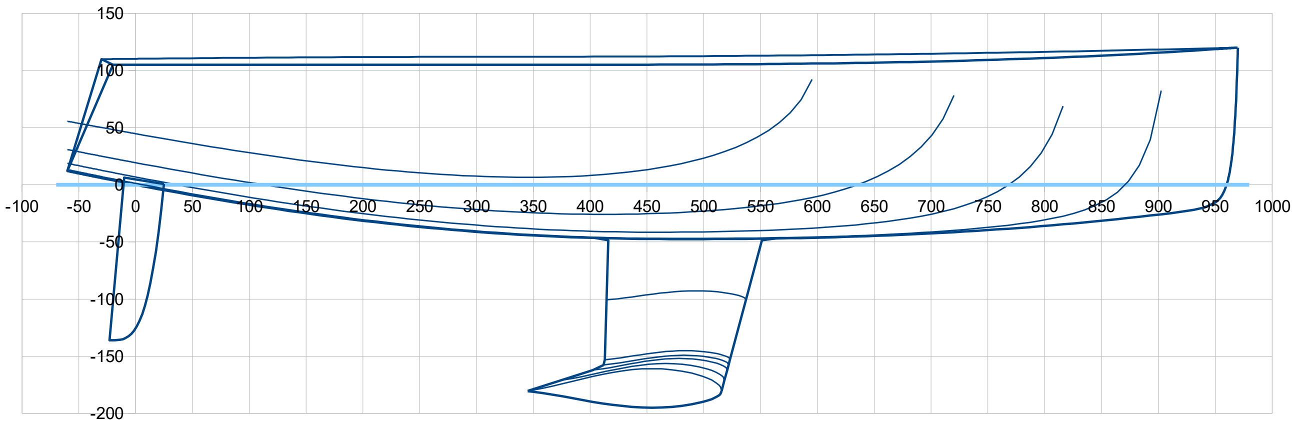


From these variants, one can retain Z tab ar ~ 0,12 as a good preliminary value, and to reduce Tc to 0,475 to stay close to the displacement objective 5950 kg. Also, we should keep in mind that the LCB (at > 48 % Lwl) is still too forward with regard to the usual range 46 to 47 to minimize the residuary drag (ref : Delft series results as reported in « Principle of Yacht Design » L. Larsson and R. Eliasson – 2000 Second edition).

Data to input :

Z tab ar (m)	**0,120**
Tc (m)	**0,475**

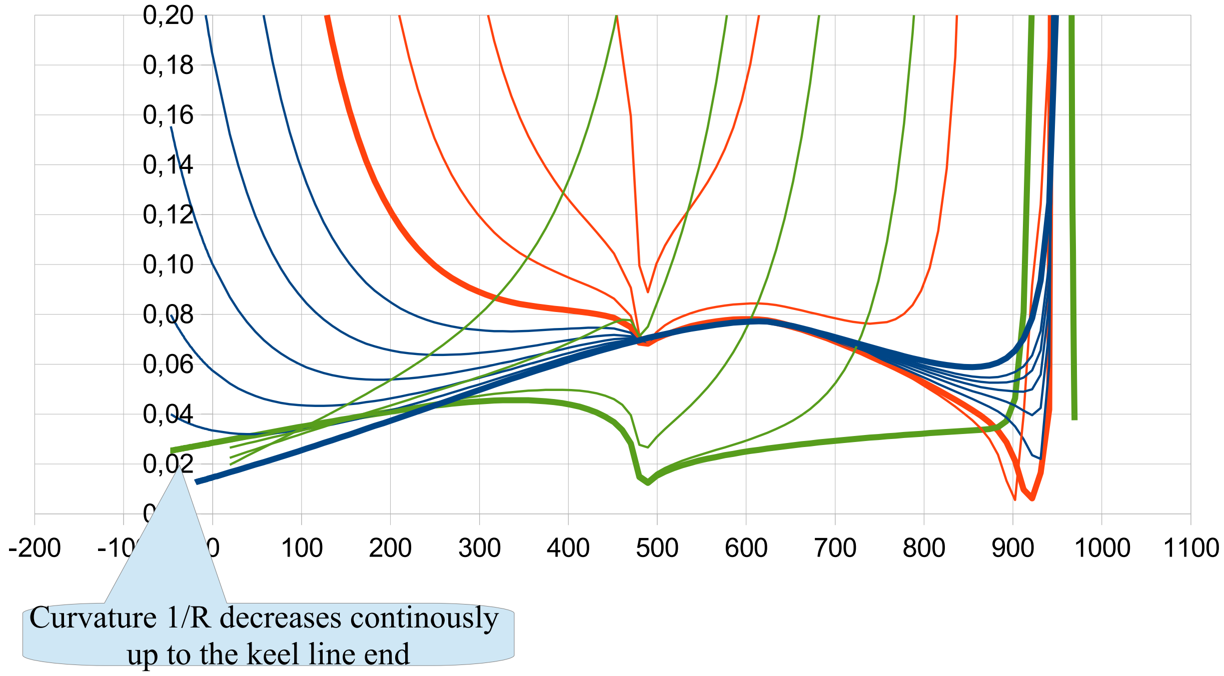
>>>



>>> from the hydrostatics output :

Displacement at H0 (kg)	**5954**	**Xc (%Lwl)**	**48,12**	**Cp (%)**	**58,49**

>>> from the 1/R curve :



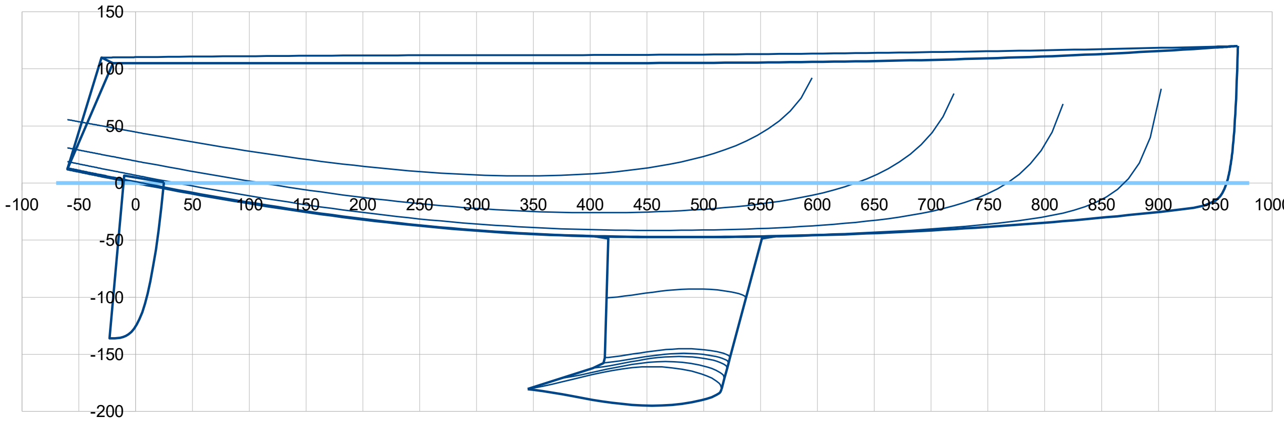
***16* Keel line global adjustment using Pui q av and Pui q ar**

After the use of Cet and Z tab ar to shape more specifically the fore and rear ends of the keel line, one can now use these 2 adimensional parameters Pui q av and Pui q ar in order to shape the whole line and especially to move a bit aft the LCB (i.e. Xc) .

When increasing Pui q av, you increase the fore half of the displacement, and vice versa.

When increasing Pui q ar, you increase the rear half of the dispacement, and vice versa.
When increasing both 2 parameters, you increase the displacement and also the prismatic coefficient Cp, and vice versa.
Here we will increase Pui q ar and drecrease Pui q av in order to move LCB a bit aft at equivalent displacement.

Initial values		>>>>	New values	
Polynomials of the keel line,				
Pui q av	**2,35**		**2,10**	
Pui q ar	**2,20**		**2,40**	
giving :			**giving :**	
Xc (%Lwl)	**48,12**		**Xc (%Lwl)**	**47,73**



17 Sections adjustment using available adimensional parameters

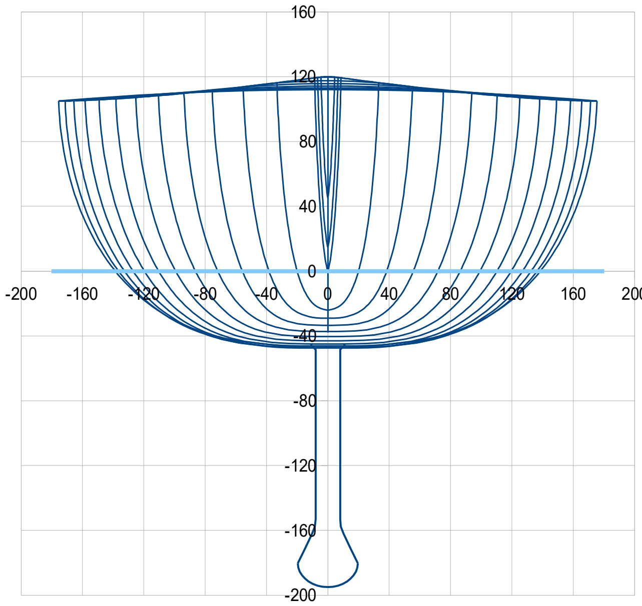
We can now have a look at the sections : their ends are given by the keel and the sheer lines now defined, their shape are steered by adimensional parameters : 7 for the U shape, 1 for the E shape, 3 for the combination UE, the User guide details with illustrations the role and effect of each one. Yet, I must confess that it is the less intuitive part of the adjustment, you have to test with some back and forth up to reach the given objectives.

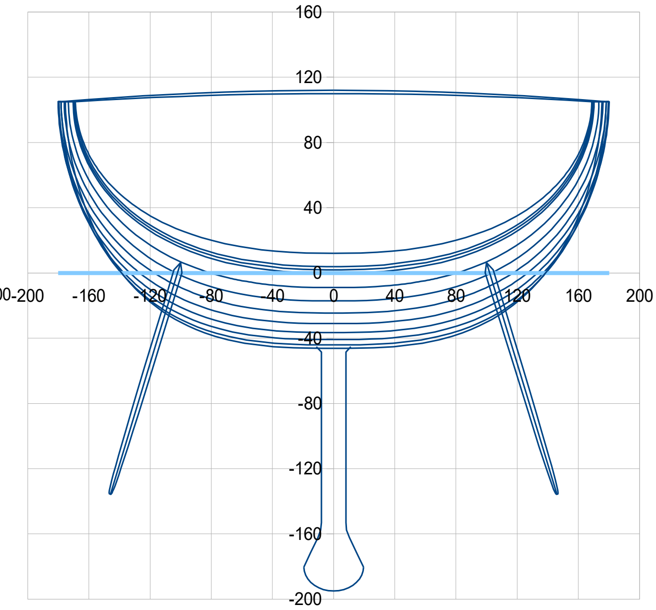
The present situation :

Sections U :		
C Hu av	**0,25**	
C Hu ar	**0,46**	
Pui Hu	**1,00**	
Pui U av	**8,00**	
Pui U ar	**15,00**	
Pui Pui U	**4,00**	
Cor Pui Pui U	**0,00**	
Sections E and combination UE :		
Pui E	**2,36**	
mix UE av	**0,60**	Front mix, should be between 0 and 1 (1 = « U », 0 = « E »)
mix UE ar	**0,00**	Rear mix, should be between 0 and 1
Pui mix UE	**1,00**	

\>>> giving (from hydrostatics output data) :

Bwl (m)	**2,78**	**at X (% Lwl)**	**37,0**	> Bwl/B	0,771
Xc (%Lwl)	**47,73**	**Cp (%)**	**58,27**	**Displacement at H0 (kg)**	**5948**





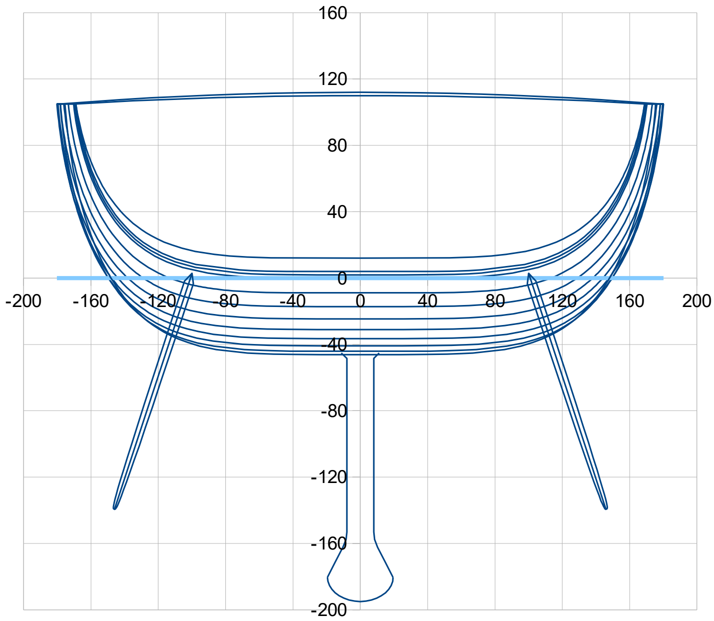
At this stage, we have the objectives to move more aft the LCB (< 47 % Lwl at least, according to PYD recommendation to minimise the residuary drag), while maintaining Cp around 0,58-0,59 (to favor high speed of planning if any), and a ratio Bwl/B that could be at least 0,77 (for the righting moment).

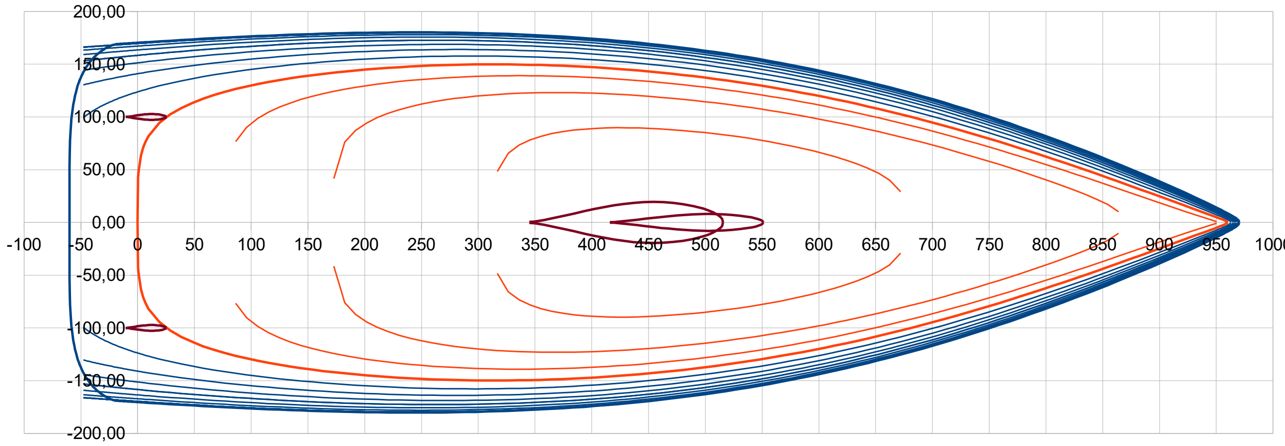
Let's test **mix UE ar = 0,7**, instead of 0, to introduce a 70% dose of U shape and a 30% dose of E shape in the rear sections (instead of 0% U shape and 100% E Shape) >>> The U shapes becomes very apparent, bringing more Bwl and more rear volume :

Data to input :

mix UE ar	**0,70**

>>>





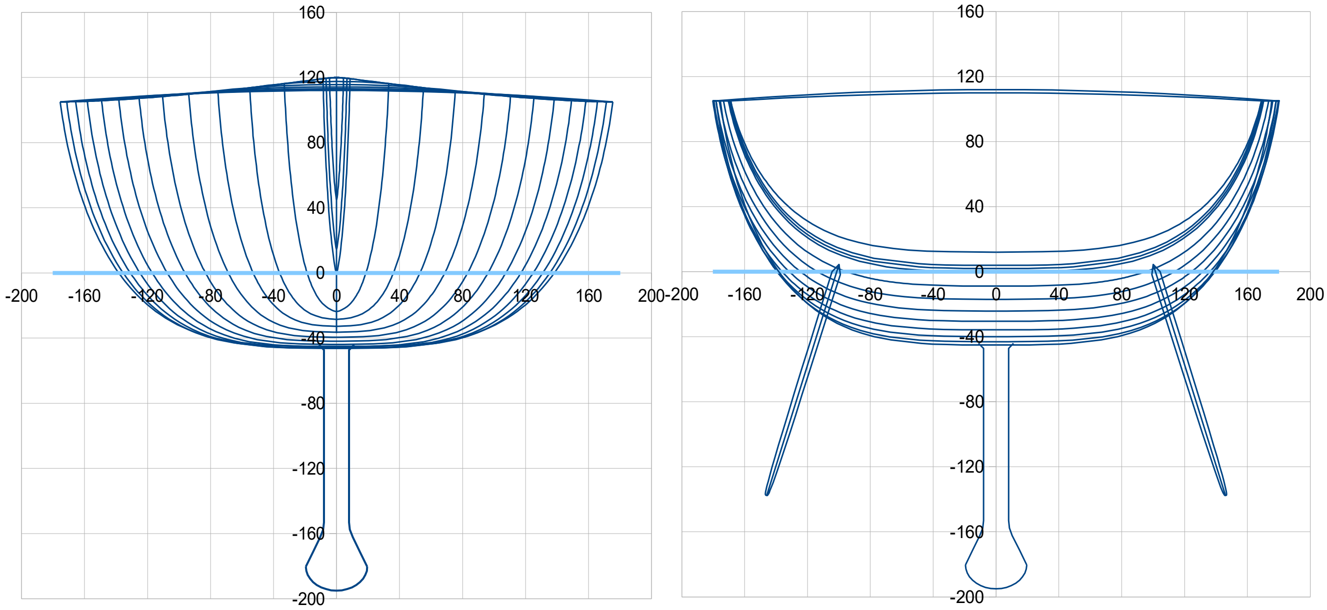
Bwl (m)	**3,00**	**at X (% Lwl)**	**33,0**	> Bwl/B	0,832
Xc (%Lwl)	**46,20**	**Cp (%)**	**58,69**	**Displacement at H0 (kg)**	**6863**

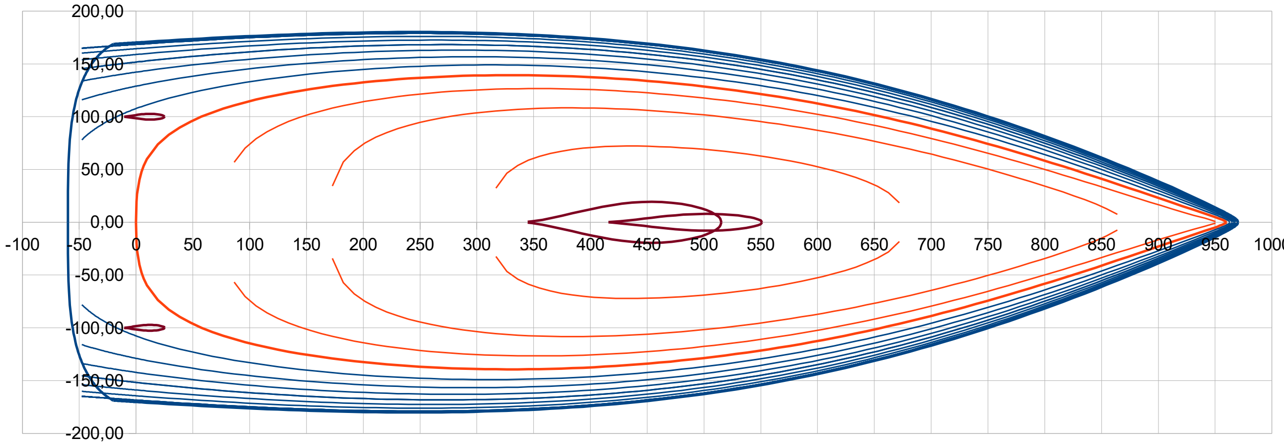
Ratios evolves towards the objectives, but the displacement is a lot too much at 6863 kg, so the second step is to reduce the power of this U rear shape , i.e. to decrease Pui U ar. >>> with **Pui U ar = 8** and a slight reduction of the hull draft **Tc to 0,463 m,** the ratios and the displacement converge towards the objectives :

Data to input :

Pui U ar	**8,00**
Tc (m)	**0,463**

>>>





Bwl (m)	**2,79**	**at X (% Lwl)**	**34,0**	> Bwl/B	0,773
Xc (%Lwl)	**46,50**	**Cp (%)**	**58,43**	**Displacement at H0 (kg)**	**5960**

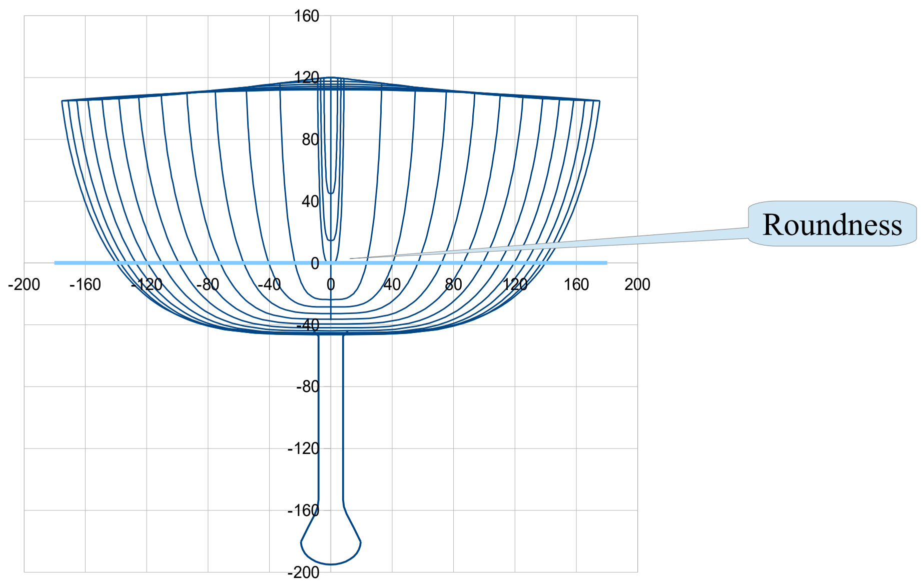
18 Fore sections fine tuning using C Hu av

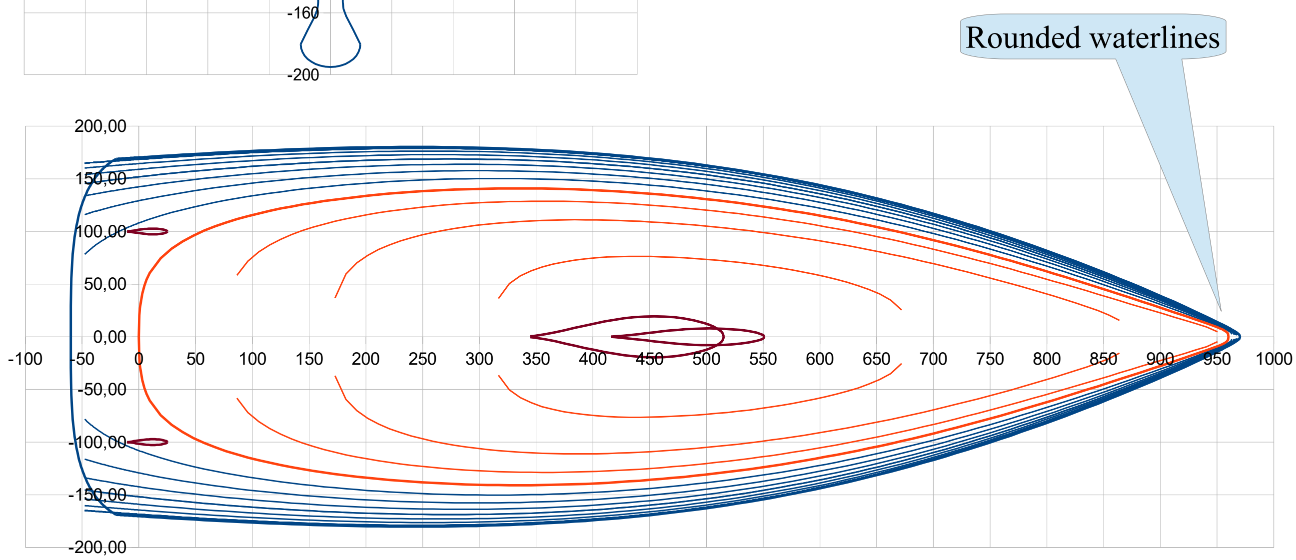
This parameter acts on more or less roundness of the lower part of the U of the fore sections. The more C HU av > 0, the less this roundness. Before choosing the right one, let's test with C Hu av =0 and 0,5 to show its influence (the present value at this stage being 0,25).

Data to input :

C Hu av	**0,00**

>>>

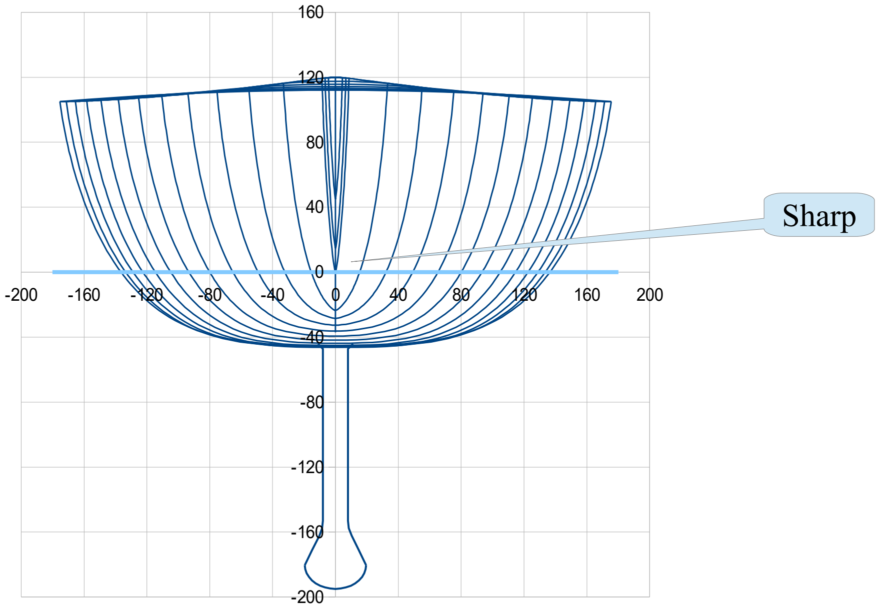


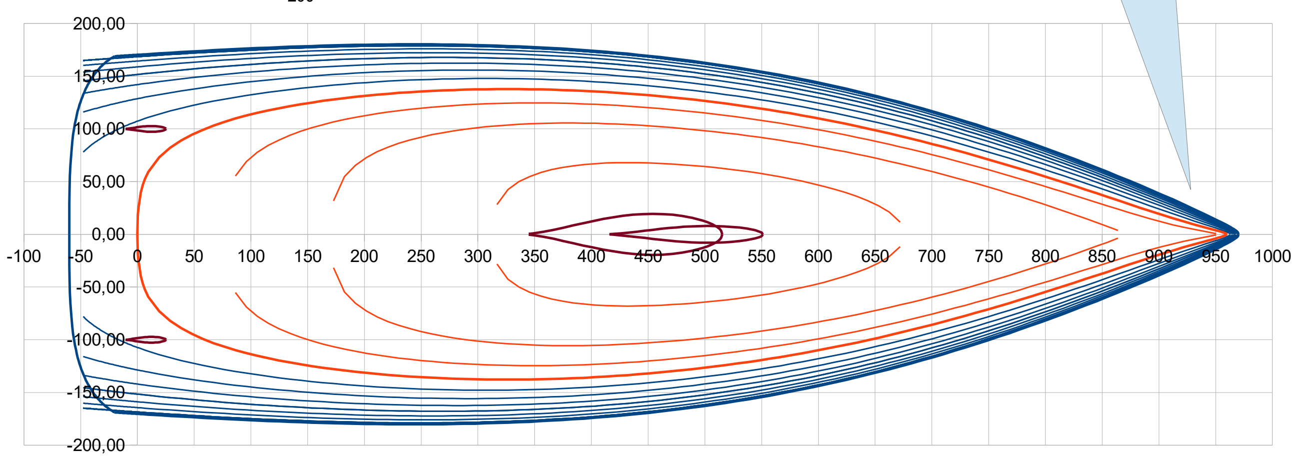


Data to input :

C Hu av	**0,50**

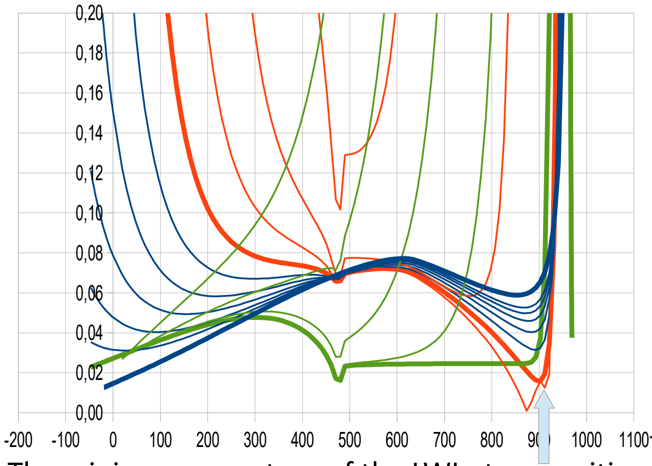
>>>

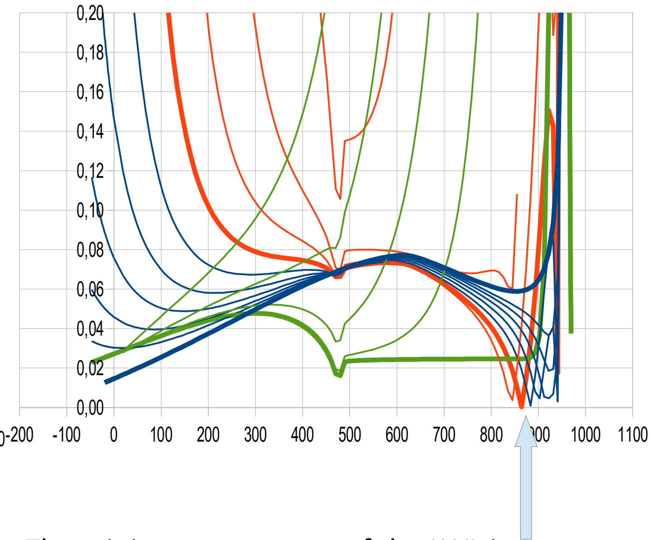




To have a fine vision of the frontier betweeen rounded and pinched waterlines, one can refer to the curvature 1/R curves :

C Hu av = 0 >>>> C Hu av = 0,5





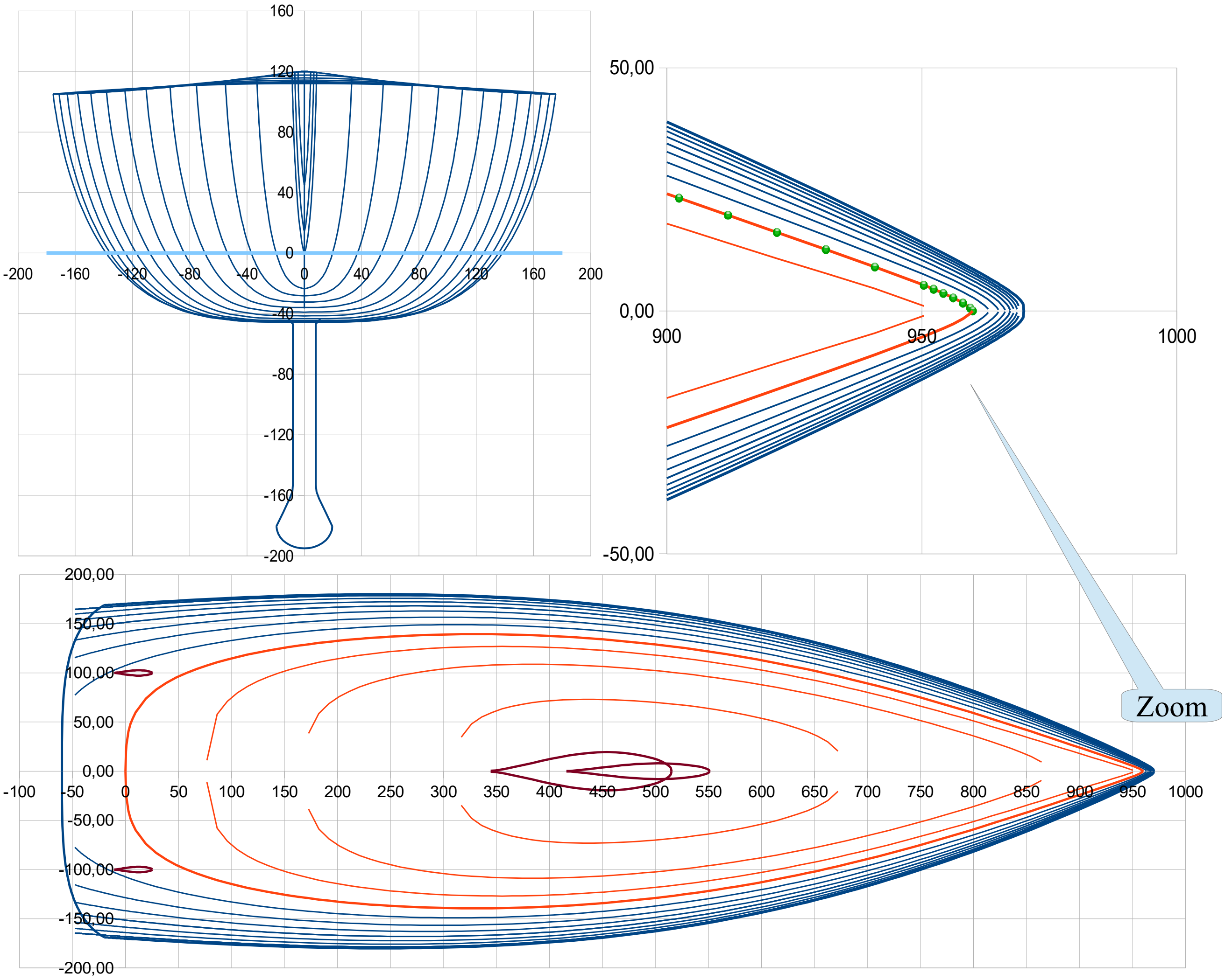
The minimum curvature of the LWL stays positive , so no pinched line.

The minimum curvature of the LWL is zero, meaning an inflexion point.

When searching a C Hu av which can lead to this frontier while avoiding the pinched lines, **C Hu av = 0,19** seems better than the previous 0,25 with, to maintain the displacement objective, a hull draft Tc(m) adjusted to 0,458. **Data to input :**

C Hu av	0,19	Tc (m)	0,458

>>>

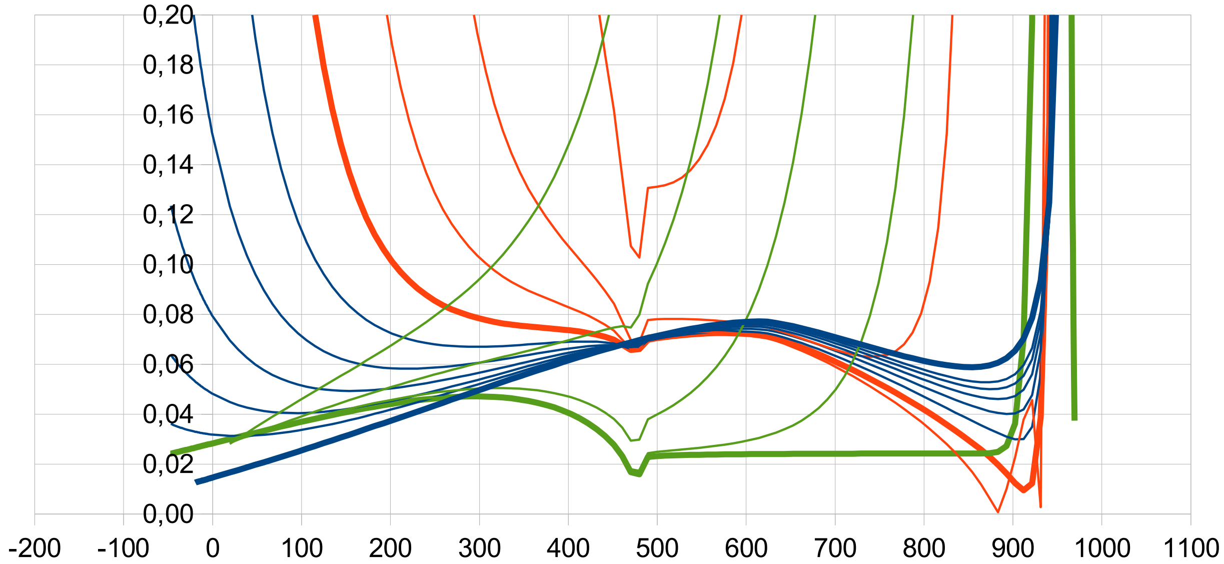


The bow waterlines, LWL and above, are not pinched before the transition to the very end roundness. Only the first waterline below the LWL shows a slight pinched, but it is ok.

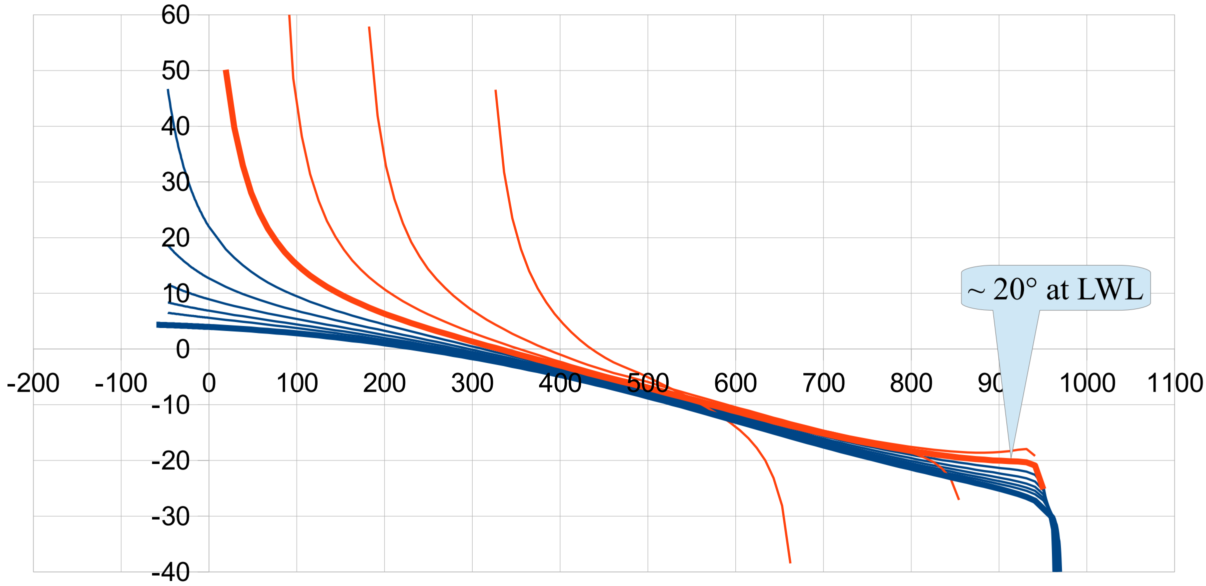
Angles (°) of the water lines (in horizontal projection xy)

Red : waterlines below H0 **(thick line = H0)**

Blue : waterlines above H0 **(thick line = sheer line)**



The curves of the waterlines angles are very regular and the half angle of entrance is ~ 20° .



At this stage, it seems not necessary to further adjust the sections parameters. The present set of parameters for the sections is now :

Sections U :	
C Hu av	0,19
C Hu ar	0,46
Pui Hu	1,00
Pui U av	8,00
Pui U ar	8,00
Pui Pui U	4,00
Cor Pui Pui U	0,00
Sections E and combination UE :	
Pui E	2,36
mix UE av	0,60
mix UE ar	0,70
Pui mix UE	1,00

and the main outputs are now :

Bwl (m)	**2,79**	**at X (% Lwl)**	**34,0**	> Bwl/B	0,774	
Xc (%Lwl)	**46,61**	**Cp (%)**	**58,67**			
Displacement at H0 (kg)	**5948**	**Ballast (kg)**	**2141**		*DLR*	*187*

19 Sailplan first definition

At first to remind the objectives inspired by the Delher 34 2017 :
I = 13,60 m ; J = 3,87 m ; P = 13,25 m ; E = 4,95 m ; Hmast ~ 16,3 m ; Zboom ~ 2,5 m
Data to enter in the sailplan sheet are :

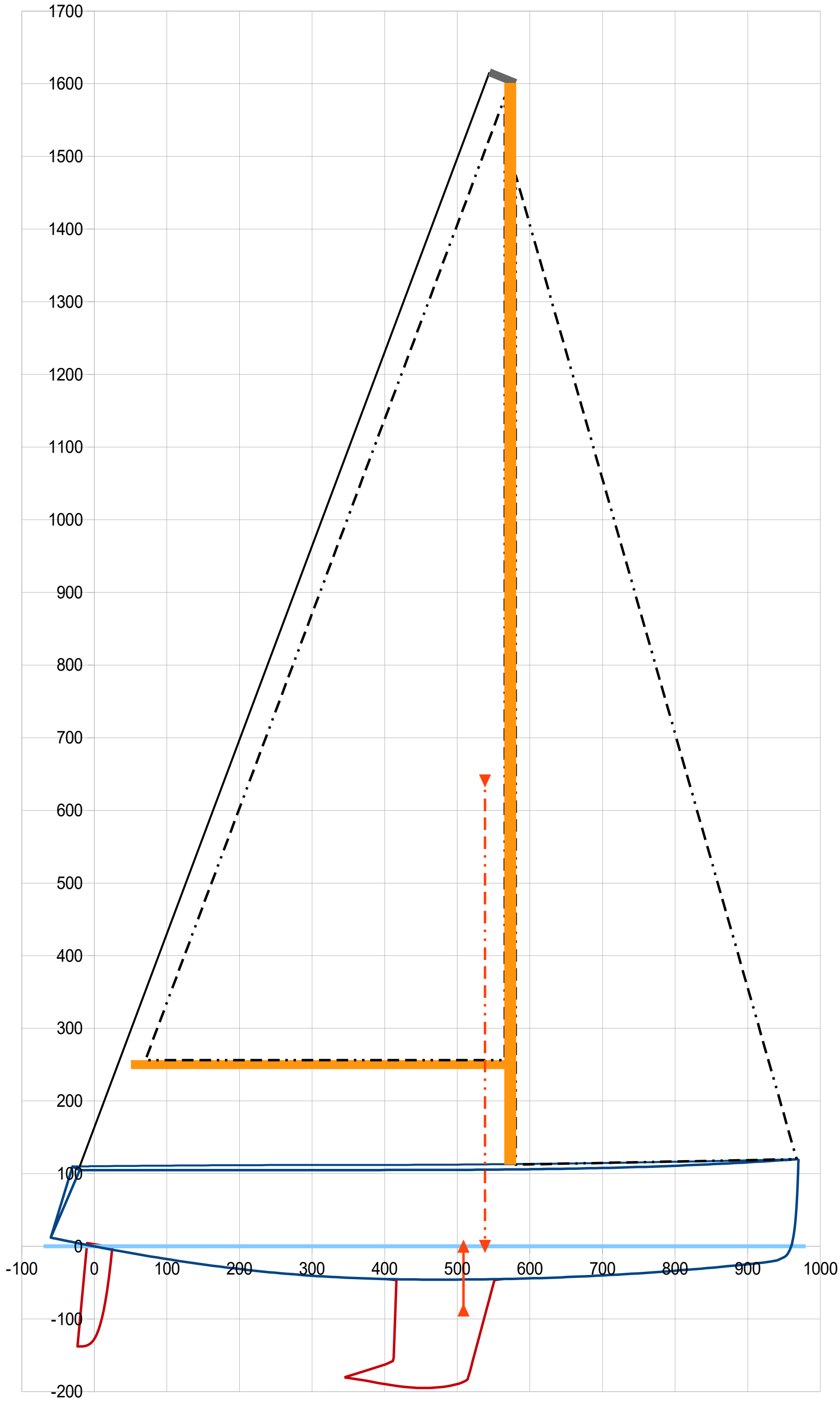
Xmast (m)
Zboom(m)
I (m)
J (m)
P (m)
E (m)

For Xmast , the value can be derived from X bow and from J :

Xmast = Xbow - J - 0,1 = 9,70 – 3,87 - 0,1 = 5,73 m

So, data to input are : >>>> and the output are :

Data to enter		**Results for the Sailplan (i.e. Fore + Main triangles)**				
Xmast (m)	**5,73**	**Geometrical center**				
Zboom(m)	**2,50**	Xv (m)	5,381	Zv (m)	6,407	
I (m)	**13,60**	**Surface triangles St (m2)**		**59,11**	*636,25*	*sqft*
J (m)	**3,87**	>> St / Sw		2,11	*PYD : 2 to 2,5, average 2,25*	
P (m)	**13,25**	>> St / D^(2/3)		18,30	*PYD : 15 to 22, average 19*	
E (m)	**4,95**	>> Skeel / St (%)		2,90	*PYD : ~ 2,75% (racing) to ~ 3,5 % (racing/cruising)*	
		>> Srudder / St (%)		0,77	*PYD : 1 to 2, average 1,4%*	
		Lead (Xv – CLR) (% Lwl)		**3,1**	*PYD : 3 to 7 (fractional rig), 5 to 9 (masthead)*	



« PYD » are for the statistics quoted by E .Larsson and R. Eliasson in their book « Principles of yacht Design » 2nd edition 2000.

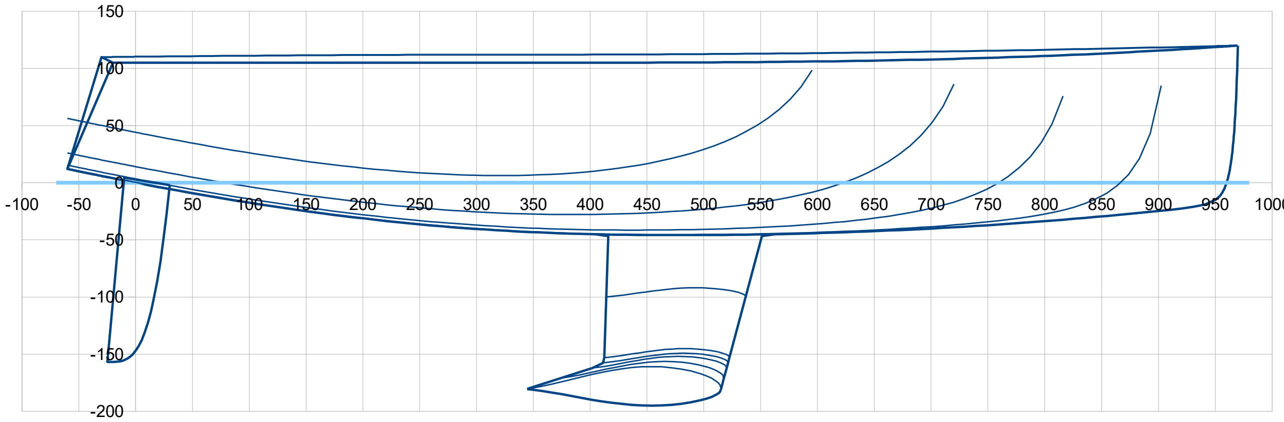
20 Rudders geometry first definition

The ratio surface of the rudders / surface of sails (triangles) is presently 0,77%, a bit low with regard the usual one although we have adopted a twin rudder configuration and the statistics in reference are for one rudder >>> we can increase a bit the root chord and the span of the rudders.

Data to input :

C root (m)	**0,40**
L ar (m)	**1,70**

>>>



>>> in the sailplan output data :

>> Srudder / St (%) 1,00

21 Mass spreadsheet early stage estimation

In this sheet, the data to input are in **bold black**, the other values coming from Gene-Hull and Sailplan sheets.

To input estimated mass units by subassembly which could be both relevant (due to your naval architect experience) and leading to a light weight mass matching with the present displacement 5962 kg. My choice :

Hull (skin, structure, keel interface) *, with S, Xs and Zs from Gene-Hull sheet*	45,97	**24,00** (kg/m2)
Deck – roof – cockpit (skin and structure) *, with S, Xs and Zs from Gene-Hull sheet*	27,47	**18,00** (kg/m2)
Rig, sails and deck fittings		**12,00** (% Disp.)
Cabin accomodation and motor		**24,00** (% Disp.)
Keel		
Rudder		**1,30** (% Disp.)

>>> that leads to :

Its : Light weight boat >>> 5962,07

Input of « Rig, sails and deck fittings » estimated Xg and Zg :
Xg (m) ~ 5,3 ; Zg (m) ~ 4,8
Input of « Cabin accomodation and Motor » estimated Xg and Zg :
Xg (m) ~ 4,3 ; Zg (m) ~ 0,2

>>> then the mass spreadsheet becomes :

Mass and Xg, Zg position – early stage estimation	**Input data**		**Results**				
Data from Gene-Hull sheet are in blue	**L or S or V**	**mass unit**	**Mass**	**Xg**	M Xg	**Zg**	M Zg
Data to enter are in bold black (inc. default value to initiate)	m or m2 or m3	**or % Disp.**	**(kg)**	**(m)**		**(m)**	
Hull (skin, structure, keel interface)	45,97	**24,00**	1103,31	4,30	4741,29	0,01	12,32
, with S, Xs and Zs from Gene-Hull sheet		(kg/m2)					
Deck – roof – cockpit (skin and structure)	27,47	**18,00**	494,51	3,84	1901,19	1,12	553,85
, with S, Xs and Zs from Gene-Hull sheet		(kg/m2)					
Rig, sails and deck fittings		**12,00**	715,39	**5,30**	3791,56	**4,80**	3433,87
		(% Disp.)					
Cabin accomodation and motor		**24,00**	1430,78	**4,30**	6152,34	**0,20**	286,16
		(% Disp.)					
Keel			2140,58	4,69	10043,37	-1,40	-2997,41
Rudder		**1,30**	77,50	0,05	3,98	-0,70	-53,98
		(% Disp.)					
	Results : Light weight boat >>>		**5962,07**	**4,467**	26633,73	**0,207**	1234,81

, and the main outputs are reported in the Gene-Hull sheet, in the last line of the hydrostatics output :

2.4 Hull + Keel + Rudder(s)							
Displacement at H0 (m3)	**5,81617**	**at Xc (m)**	**4,453**	**Xc (%Lwl)**	**46,39**	**Zc (m)**	**-0,224**
Displacement at H0 (kg)	**5962**	*>> ft*	*14,61*			*>> ft*	*-0,74*
>> lbs	*13143*						
Ballast (kg)	**2141**	**at Xg (m)**	**4,692**	**Xg (%Lwl)**	**48,87**	**Zg (m)**	**-1,400**
>> lbs	*4719*	*>> ft*	*15,39*			*>> ft*	*-4,59*
>> % Ballast	35,9						
Sw (m2)	**28,60**	>Sw/D^(2/3)	8,84	Lwl/D^(1/3)	5,34		
>> ft2	*307,87*			*DLR*	*188*	*M(lbs/2240)/(Lwl(ft)/100)^3*	
2.5 Data from the mass spreadsheet							
Light boat: M (kg)	**5962**	**at Xg (m)**	**4,467**			**at Zg (m)**	**0,207**

, where, for the final optimisation of the hull and this early stage project :

- the weight longitudinal position Xg (4,467 m) should be equal or at least very close to Xc (4,453 m),
- the vertical position of Zg will be used in the « Hull with heel » study later on.

22 Keel adjustement to better match with the sailplan and the mass spreadsheet outputs

The present issue is to have now :

- Xc = Xg (or very close to, but for the demonstration purpose of this tutorial we aim the equality)
- a « Lead » well inside the usual range (3% to 7 % Lwl)

We are not far from these objectives, so it is a fine tuning of the keel geometry and position, for which we can iterate on :

- Keel longitudinal position **Xq ar**
- Front angle **F angle**
  Xar and F angle allow to move forward or back Xg, and also decrease or increase the Lead

Present values		>>>	New input values	
Xq ar (m)	**4,16**		**Xq ar (m)**	**4,03**
F angle (°)	**75,00**		**F angle (°)**	**80,00**

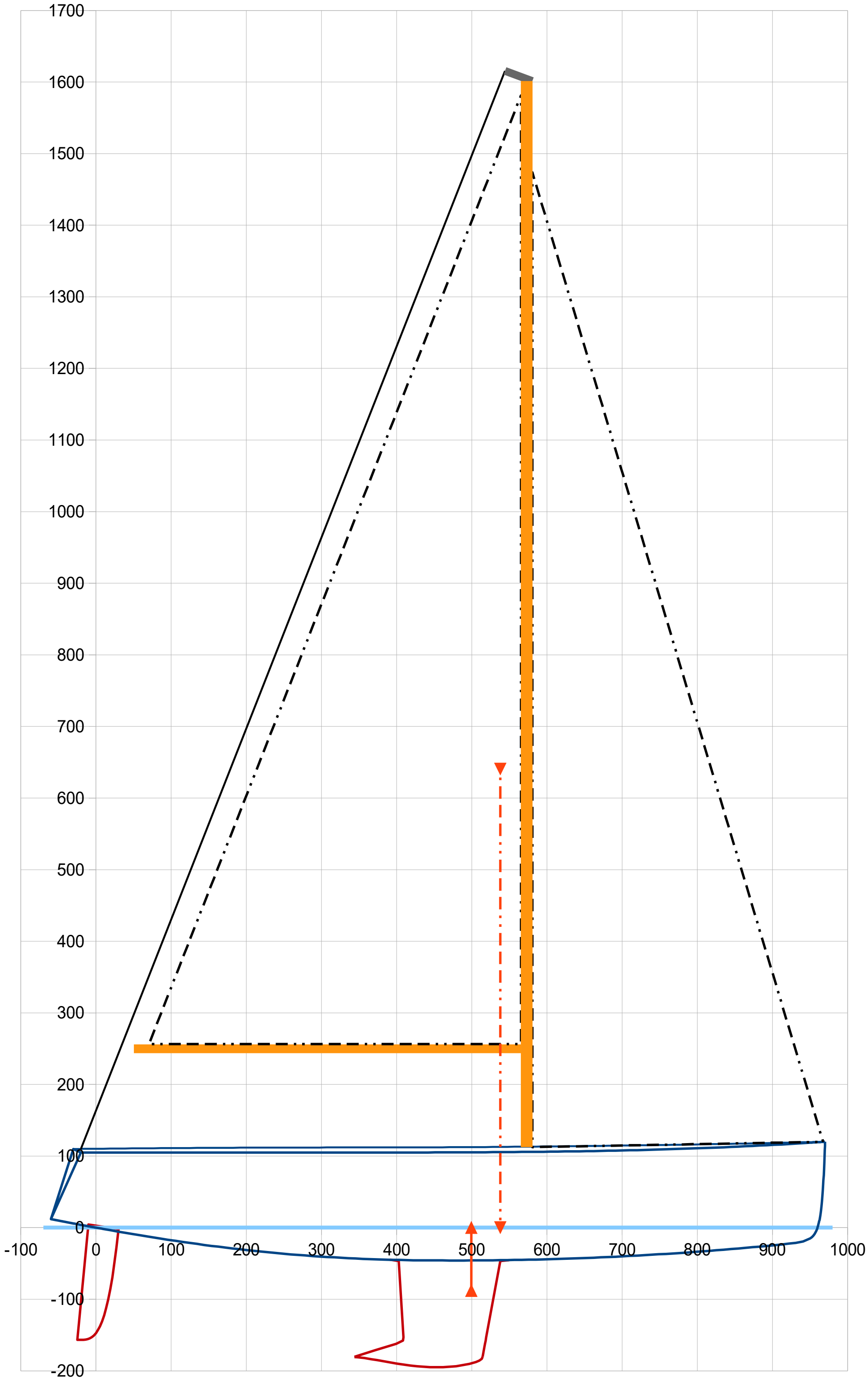
, which leads to exact equality of Xc and Xg and the Lead is now 4,0 % instead of 3,1 % :

>>> from the Gene-Hull sheet output :

Displacement at H0 (kg)		**5962**	**at Xc (m)**	**4,451**
Light boat:	**M (kg)**	**5962**	**at Xg (m)**	**4,451**

>>> from the Sailplan sheet output :

Lead (Xv – CLR) (% Lwl) **4,0**



23 Study of the Hull with heel

This application is in the output section 6 of the Gene-Hull sheet (from line 425). The data to enter :

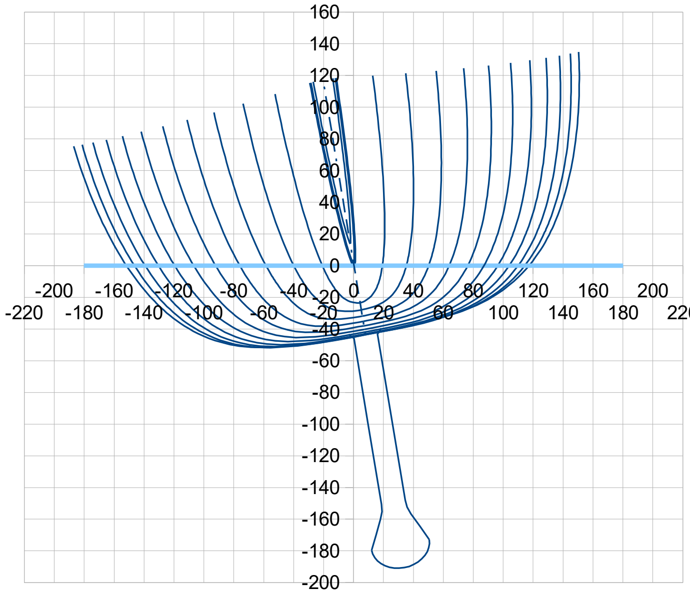
6. Hull-Keel-Rudder with heel
Data to enter
Heel (°)
Height (cm)
Trim (°)

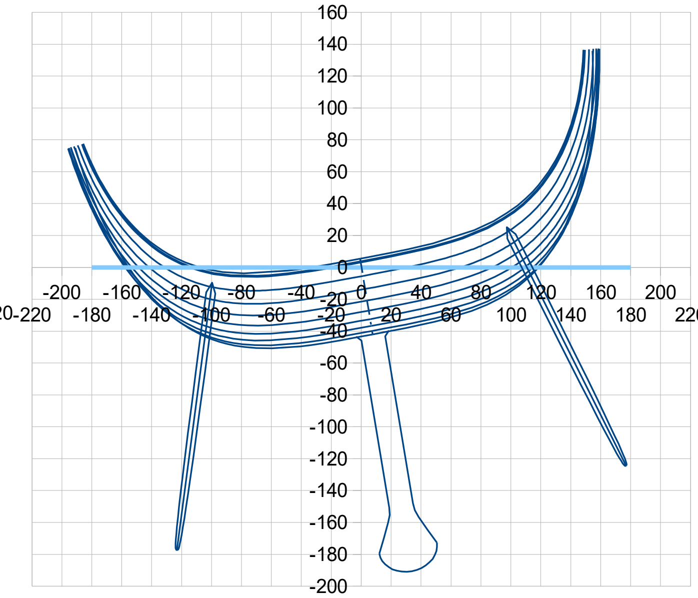
At this early stage project, one can study the hull at heel 10°, 20° and 30° , the main interesting output are the righting moment RM (and in particular the RM30° which is used for the dimensioning of the rig and its hull interfaces), the wetted surface, the floatation surface shape and its obliquity angle with the centerline, the minimum freeboard leeward (in particular at 30°).
The procedure is to input the heel angle, and then to input and iterate on the elevation height of the hull (in cm) and the trim (in °) up to have both the displacement = the weight and Xc = Xg. Negative trim = nose down.

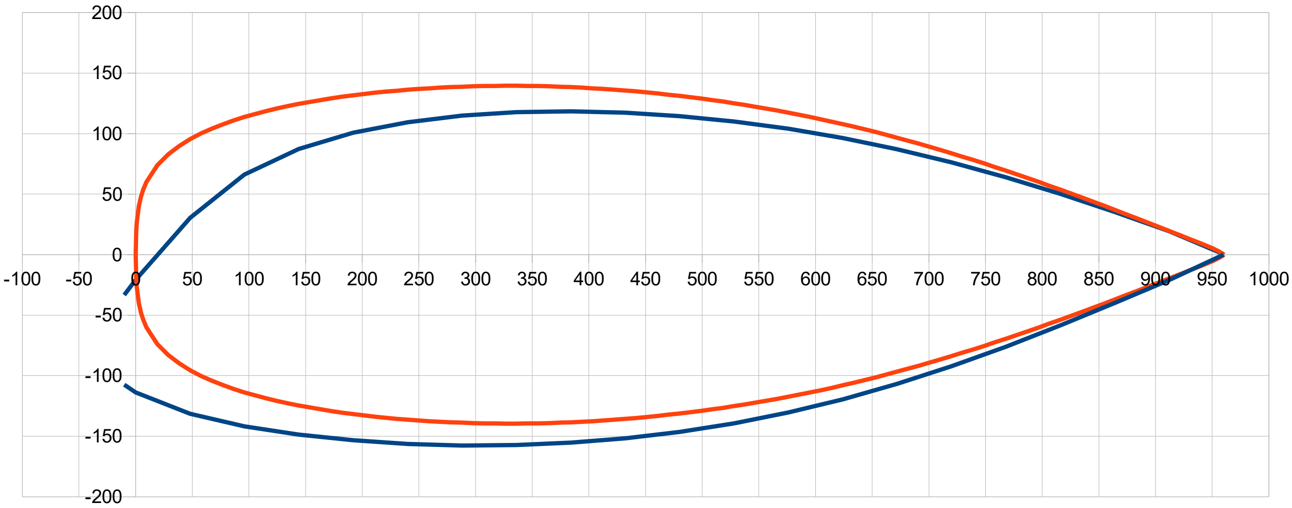
Data to enter		Results for iteration on height and trim		Data to compare with :		Other results for RM and obliquity	
Heel (°)	**10,0**			**Mass (kg)**	5962,07		
Height (cm)	**1,6392**	**Disp. (m3)**	**5,81665**	**/ Disp. (m3)**	**5,81665**	Hull Mom(m4)	1,266
Trim (°)	**-0,245**	**Xc heel (m)**	**4,451**	**/ Xg (m)**	**4,451**	Mom(kN.m)	12,73
		Other results		Xc Heel 0°	4,451	**Yg heel (m)**	**-0,036**
		Yc heel (m)	**-0,218**	Yc Heel 0°	0,000	**>> GZ (m)**	**0,182**
		Zc heel (m)	**-0,227**	Zc Heel 0°	-0,224	**RM (kN.m)**	**10,63**
		Sw heel (m2)	**28,57**	Sw Heel 0°	28,60	**Obliquity (°)**	**2,64**

Iteration on Height and Trim

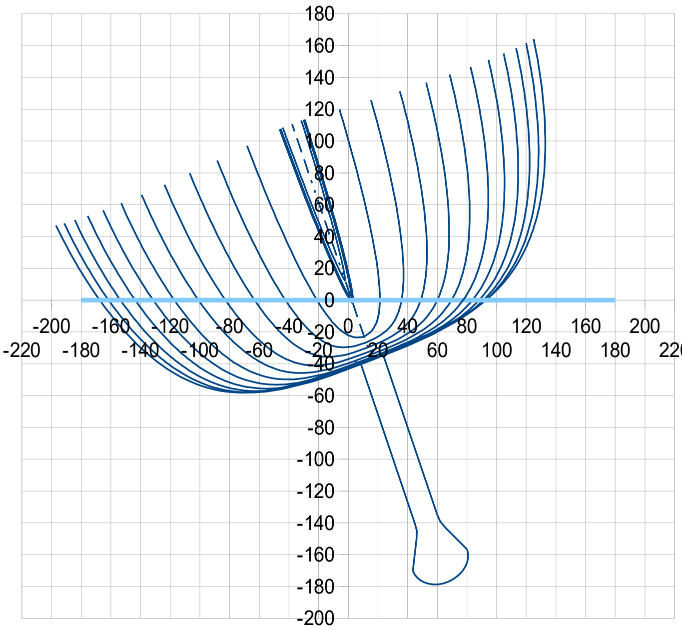
up to equalities of the Disp.

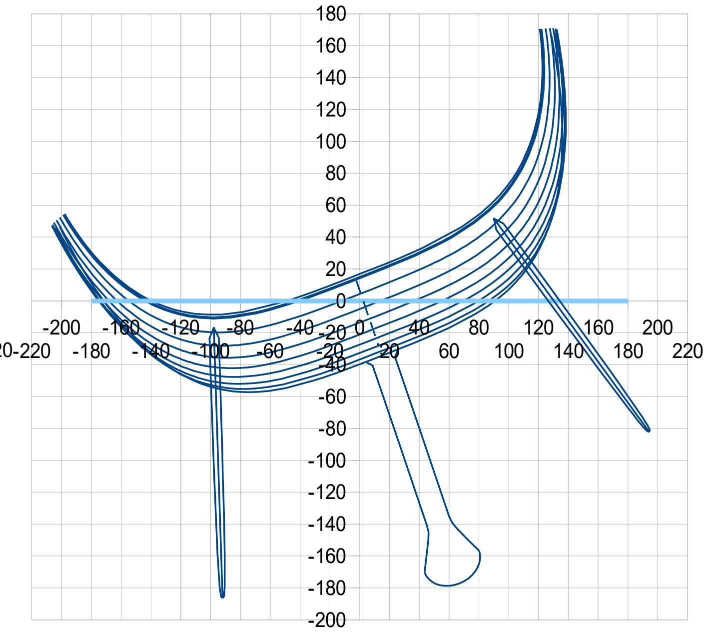


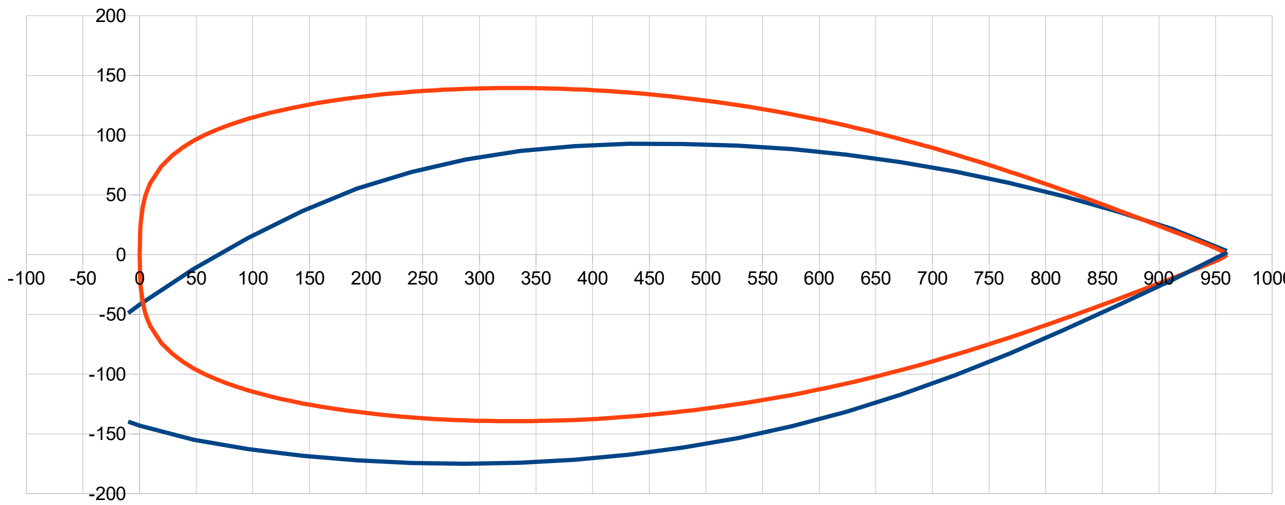




Data to enter		Results for iteration on height and trim		Data to compare with :		Other results for RM and obliquity	
Heel (°)	20,0	Disp. (m3)	5,81666	Mass (kg)	5962,07	Hull Mom(m4)	2,349
Height (cm)	6,9962	Xc heel (m)	4,451	/ Disp. (m3)	5,81665	Mom(kN.m)	23,62
Trim (°)	-0,966	Other results		/ Xg (m)	4,451	Yg heel (m)	-0,071
		Yc heel (m)	-0,404	Xc Heel 0°	4,451	>> GZ (m)	0,333
		Zc heel (m)	-0,235	Yc Heel 0°	0,000	RM (kN.m)	19,48
		Sw heel (m2)	27,91	Zc Heel 0°	-0,224	Obliquity (°)	5,30
				Sw Heel 0°	28,60		

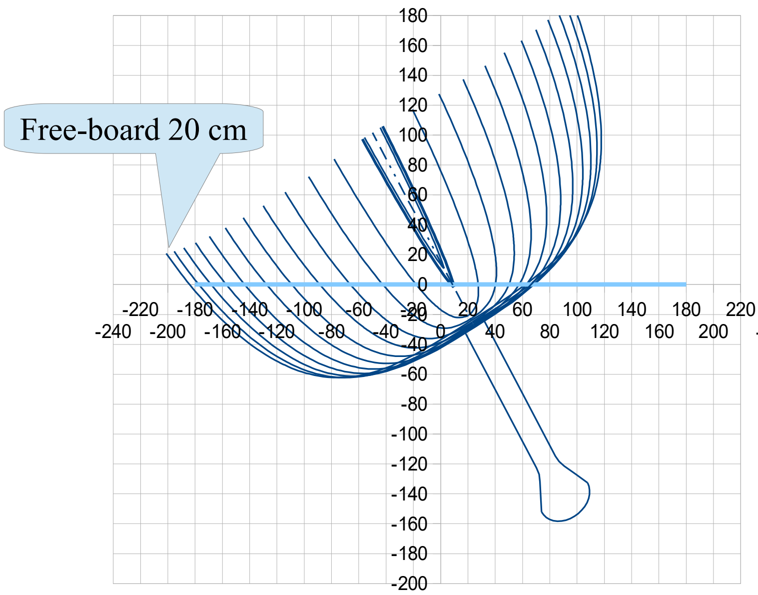


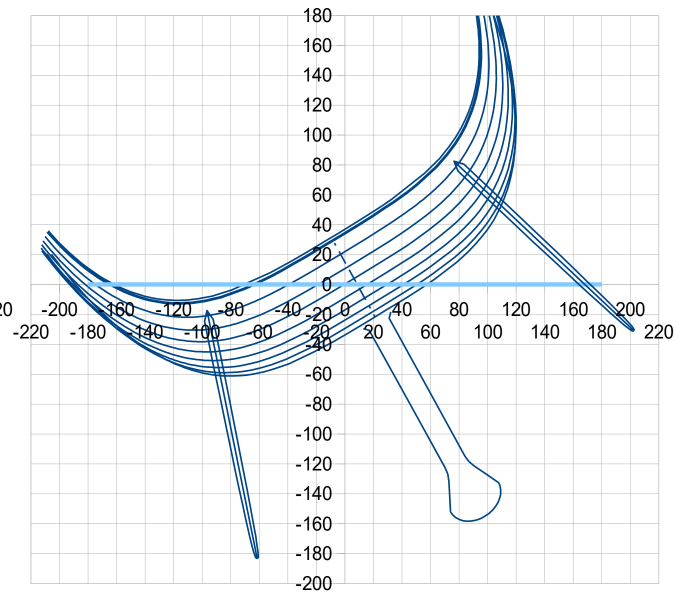


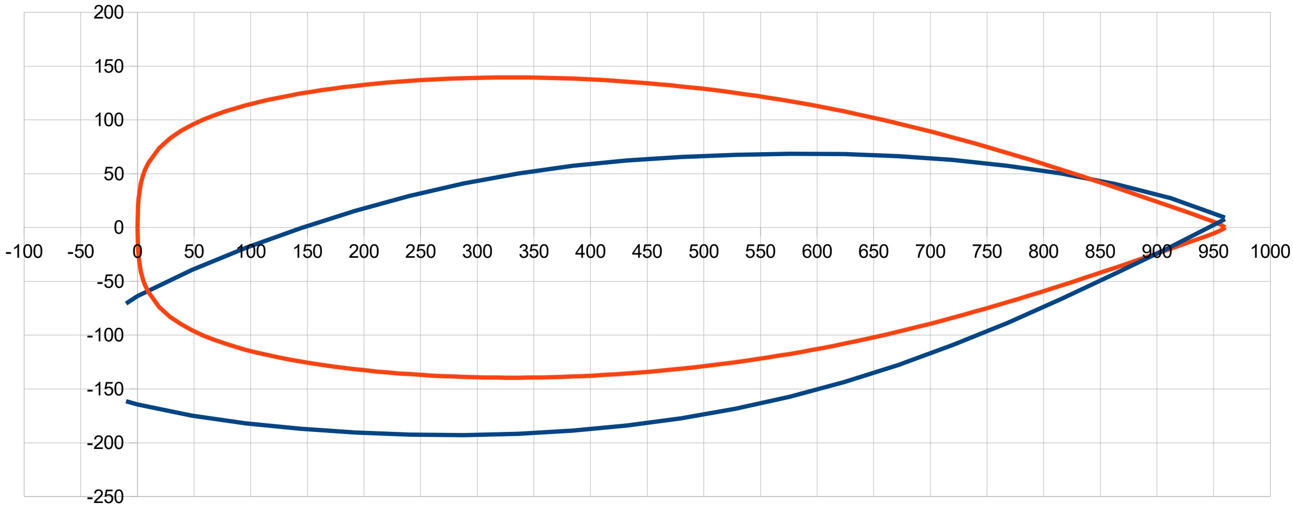


Data to enter		Results for iteration on height and trim		Data to compare with :		Other results for RM and obliquity	
Heel (°)	30,0			Mass (kg)	5962,07		
Height (cm)	17,3266	Disp. (m3)	5,81665	/ Disp. (m3)	5,81665	Hull Mom(m4)	3,144
Trim (°)	-2,155	Xc heel (m)	4,451	/ Xg (m)	4,451	Mom(kN.m)	31,61
		Other results		Xc Heel 0°	4,451	Yg heel (m)	-0,104
		Yc heel (m)	-0,540	Yc Heel 0°	0,000	>> GZ (m)	0,437
		Zc heel (m)	-0,238	Zc Heel 0°	-0,224	RM (kN.m)	25,55
		Sw heel (m2)	27,23	Sw Heel 0°	28,60	Obliquity (°)	7,37

>>> RM30° = 25,6 kN.m







With this hull with heel study, we have done a first complete design in tune with the objectives and with ratios inside their usual range, **we can called it « Tut 34 »**, and this is the end of the part one

Now we can wonder how we can improve this first version, it is the goal of the part two.

Part 2 : a second improved version (with introduction of a hard chine)

24 Optimisation, towards a new version

One ratio of the first design looks a bit weak, Bwl/B is only 0,77, this aspect will be our guideline for the new version : to try increase this ratio to let'say > 0,80 in order to have a greater righting moment while at the same time to contain as much as possible the wetted surface. And for such goal, we will use the hard chine option. At first, we have to introduce a hard chine longitudinal line, using the available input data :

Initial values :

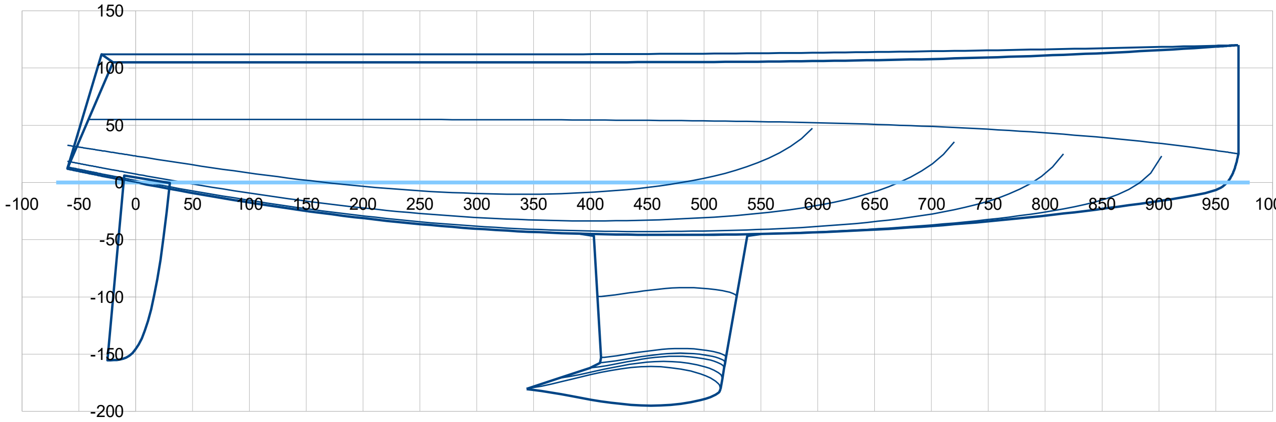
Type	**0**	**Type 0 = no hard chine** ; Type 1 = 2 points chine line ; Type 2 = 3 points chine line
1,2 Zhc av (m)	**0,18**	at Bow
2 Zhc m (m)	**0,38**	at 35% Lwl
1,2 Zhc ar (m)	**0,38**	at Aft
Pui hc z	**5**	should be > 0

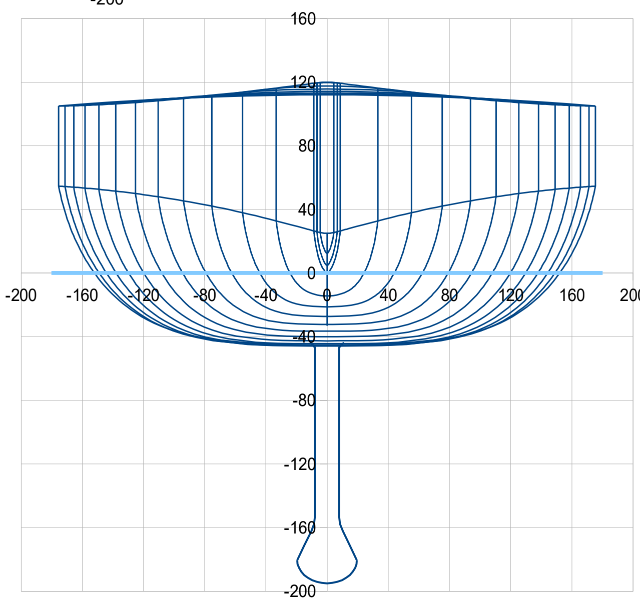
>>> we will use a Type 1 (= 2 points hard chine), with Zhc av (m) = 0,25 and Zhc ar (m) = 0,55. With Type 1, it is not necessary to specify a Zhc m.

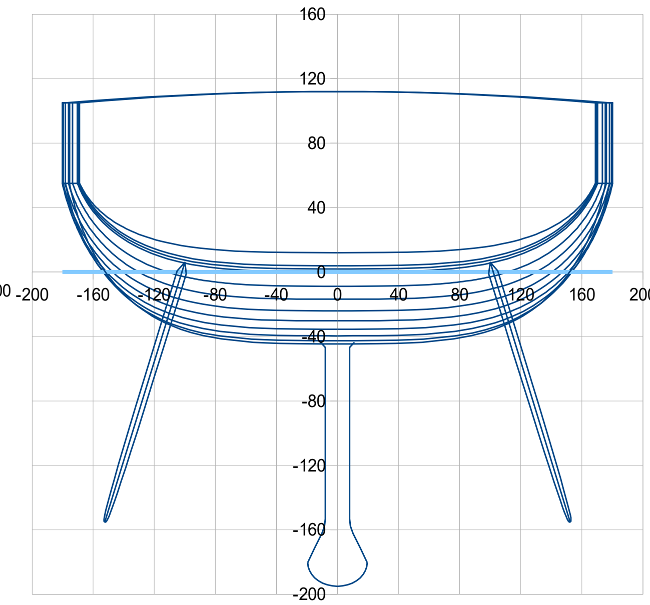
New data to input :

Type	**1**
1,2 Zhc av (m)	**0,25**
2 Zhc m (m)	**0,38**
1,2 Zhc ar (m)	**0,55**
Pui hc z	**5**

>>>







>>> from the hydrostatics output :

Bwl (m)	**3,07**	**at X (% Lwl)**	**33,0**	> Bwl/B	0,852
Displacement at H0 (kg)	**6535**				
Light boat: M (kg)	**6222**				

the ratio Bwl/B jumps to 0,852, but the displacement is now 6535 kg and no longer match with the weight 6222 kg estimation (when using the same mass units per subassembly), so next steps of adjustment should include a decrease of the displacement.

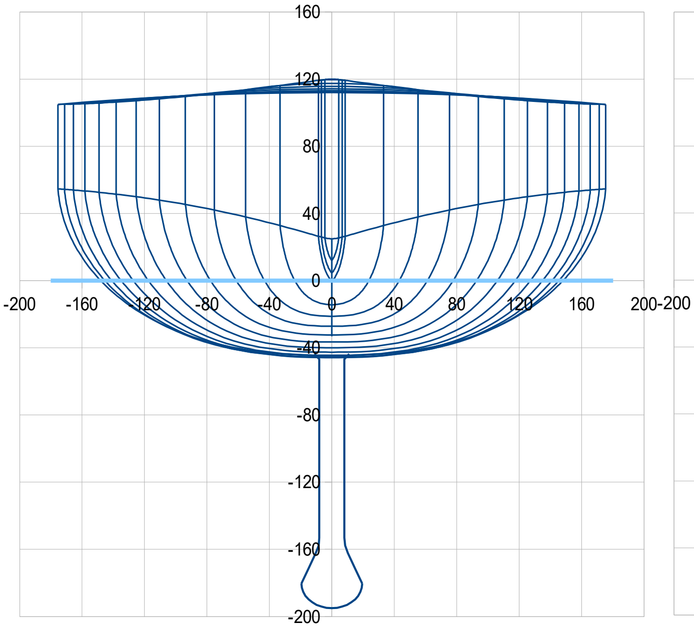
25 Sections new step of adjustement

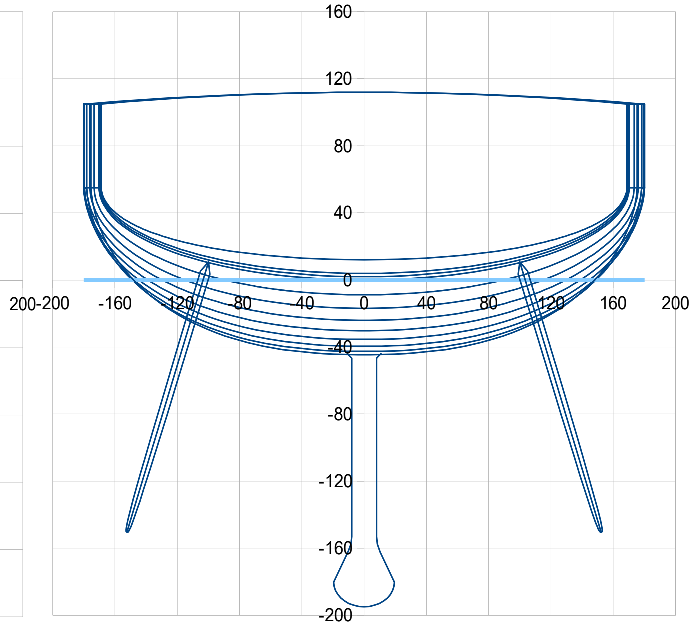
Now that we start from a high Bwl/B ratio, we can test a less U flat sections by introducing more roundness and expect less wetted surface, through more E shape with a lower degree, i.e. by the input of **Pui E = 2** (instead of 2,36) and a **mix UE ar = 0** instead of 0,7.

Data to input :

Pui E	**2,00**
mix UE ar	**0,00**

>>> then the sections shape, especially the central and aft ones, are significantly more rounded :





>>> from the hydrostatics output :

> Bwl/B	0,827	**Displacement at H0 (kg)**	**5853**	**Ballast (kg)**	**2141**
		Light boat: M (kg)	**5954**		

The displacement decreases and is now below the boat weight while the Bwl/B is still at 0,827 over the objective. Another figure, the ballast weight, can be change to be more close to the objective 2100 kg.

26 Ballast weight reduction

A slight reduction of the thickness of the bulb, **Th bulb (m) = 0,38** instead of 0,39 is sufficient to be at 2109 kg , close to the objective 2100 kg.

Data to input :

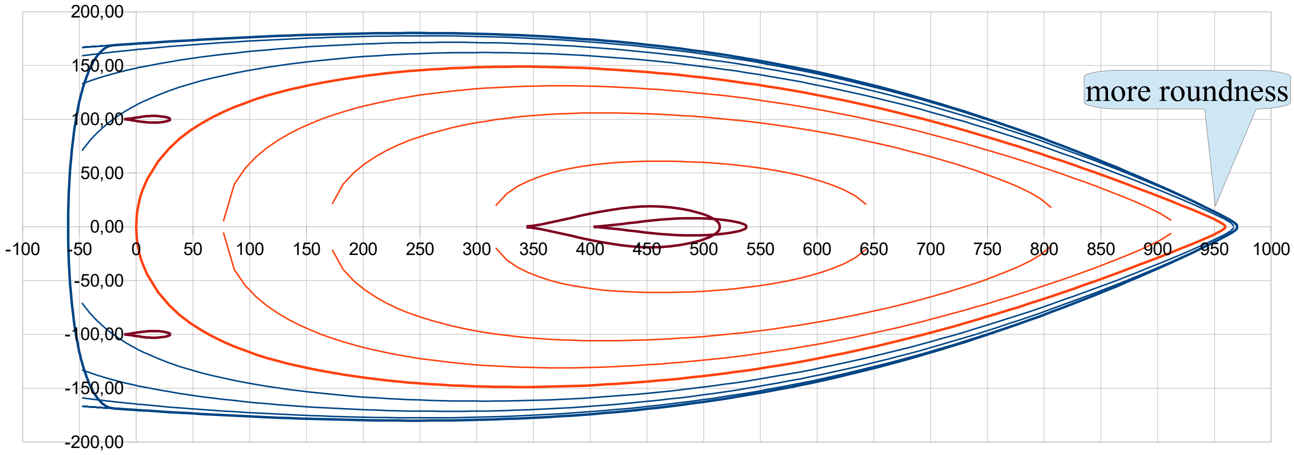
Th bulb(cm)	**38,00**

>>> from the hydrostatics output :

Displacement at H0 (kg)	**5850**	**Ballast (kg)**	**2109**
Light boat: M (kg)	**5922**		

***27* To fine tune the fore end of the Lwl**

The introduction of the hard chine has also modified the fore end of the Lwl, bringing a bit more roundness :

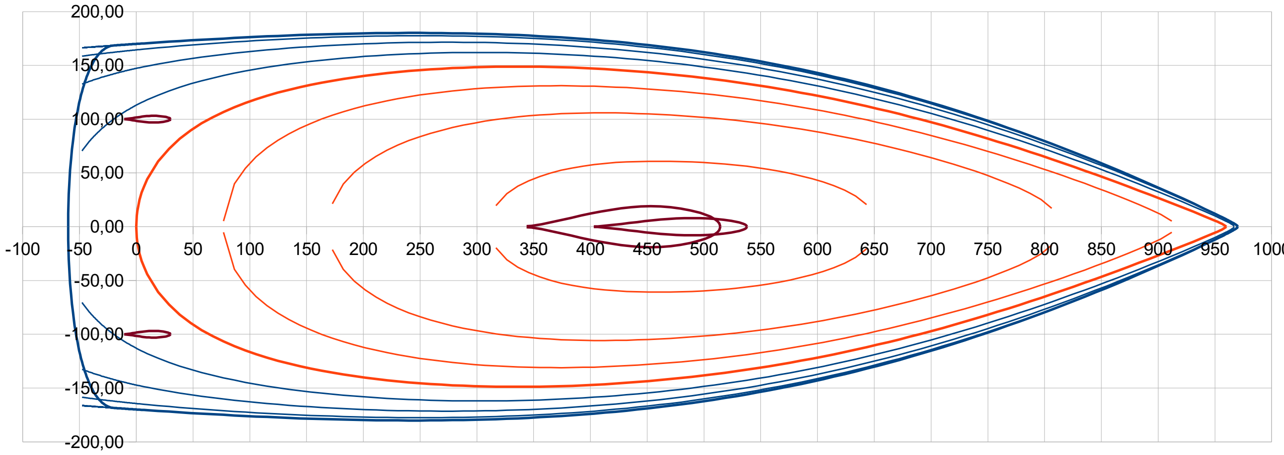


, this not derisable local effect can be compensated by adopting a lower **« Scow » = 0,03** instead of 0,06.

Data to input :

Scow	**0,03**

>>>



>>> and its influence on the hydrostatics output :

> Bwl/B	0,826		
Displacement at H0 (kg)	**5819**	**Ballast (kg)**	**2109**
Light boat: M (kg)	**5904**		

***28* To return to the equilibrium Displacement = Weight**

The displacement should be increased up to balance the weight. For this adjustment the simplest is to increase the hull draft **Tc**, and for a fine tuning at the end, one can also used **Pui Hu** wich acts on the U part of the UE sections.

Data to input :

Tc (m)	**0,467**

>>> from the hydrostatics output :

> Bwl/B	0,829	**Displacement at H0 (kg)**	**5936**	**at Xc (m)**	**4,466**
		Light boat: M (kg)	**5941**	**at Xg (m)**	**4,440**

Data to input :

Pui Hu	**0,80**

>>> from the hydrostatics output :

> Bwl/B	0,830	**Displacement at H0 (kg)**	**5945**	**at Xc (m)**	**4,467**
Sw (m2)	**29,30**	**Light boat: M (kg)**	**5945**	**at Xg (m)**	**4,440**
		Ballast (kg)	**2101**		

and for the hull alone :

Xc (%Lwl)	**46,79**	**Cp (%)**	**57,48**

We have now an exact equilibrium Displacement = Weight, moreover very close to the objective 5950 kg.

As the hull draft has increased at constant keel draft, the ballast weight has decreased a bit to 2101 kg, also very close to the objective 2100 kg.

Xg is very close but a bit aft of Xc, it is not really a disadvantage as, with heel, the boat will trim nose down as already seen with the first version : this offset of Xg can help reduce such trim.

The ratio Bwl/B is now 0,83, large over the minimum goal 0,8 which guided this new version. We have now to check, through the hull with heel study, what is the % gain of RM we have got eventually.

We have also to keep an eye on the wetted surface, now 29,30 m2 (hull upright) to compare with the previous 28,60 m2, so a slight increase of + 2,5 %.

***29* Fine tuning of the sailplan**

This fine tuning of the sailplan aims to increase the sails (triangles) surface to compensate at least partly the increase of the wetted surface, at constant mast and boom dimensions to stay at constant weight and heeling arm. Other constraint is the Lead (to stay at 4% at least) and the Xg (to stay very close aft to Xc).

A solution can be :

- to move back the mast of 5 cm and to increase J of 5 cm >>> **Xmast (m) = 5,68 and J(m) = 3,92**

- to increase I of 30 cm >>> **I(m) = 13,90**
- to decrease Zboom of 10 cm and to increase P of 10 cm >>> **Zboom (m) = 2,40 and P(m) = 13,35 m**
- In the Gene-Hull input data : slightly move back the keel of 2 cm (to maintain a sufficient Lead) and increase the length of the rudders by 2% (to anticipate the increase of the sail surface) >>> **Xq ar (m) = 4,01 and Lar (m) = 1,73**
- In the Mass spreadsheet data : to move back the Xg of the Rig subassembly >>> **5,25**

All these small adjustments allow an increase of the sails (triangles) surface to 60,29 m2 instead of 59,11 previously, **so +2%**, the lead is still at 4% Lwl and boat Xg = 4,427 m / Xc = 4,466 m (with using the hull with heel subroutine, that gives a trim of just 0,12° nose up)

Sailplan initial data		>>> **new data to input :**
Xmast (m)	**5,73**	**5,68**
Zboom(m)	**2,50**	**2,40**
I (m)	**13,60**	**13,90**
J (m)	**3,87**	**3,92**
P (m)	**13,25**	**13,35**
E (m)	**4,95**	**4,95**

>>> output of the sailplan :

Results for the Sailplan (i.e. Fore + Main triangles)			
Geometrical center			
Xv (m) 5,359	Zv (m)	6,407	
Surface triangles St (m2)	**60,29**	*648,91*	*sqft*
>> St / Sw	2,05	*PYD : 2 to 2,5, average 2,25*	
>> St / D^(2/3)	18,67	*PYD : 15 to 22, average 19*	
>> Skeel / St (%)	2,83	*PYD : ~ 2,75% (racing) to ~ 3,5 % (racing/cruising)*	
>> Srudder / St (%)	1,00	*PYD : 1 to 2, average 1,4%*	
Lead (Xv – CLR) (% Lwl)	**4,0**	*PYD : 3 to 7 (fractional rig), 5 to 9 (masthead)*	

To note that Zv (representative of the heeling arm) is strictly the same.

30 RM and Sw of the new version with heel , and comparison

To finalize this new version(named it **Tut 34 HC**, stnads for Hard Chine) and make a full comparison with the previous one (**Tut 34** of the part one), let's determine the equilibrium for heel 10°, 20° and 30° in order to know in particular the righting moment RM and the wetted surface Sw and to compare with the previous version. To remind that the input for that subroutine are :

- to set the heel angle,
- to iterate on Height and on Trim up to equality of the Displacement and Xc = Xg

Heel = 10°

Data to enter		**Results for iteration on height and trim**		**Data to compare with :**		**Other results for RM and obliquity**	
Heel (°)	**10,0**			**Mass (kg)**	5945,04		
Height (cm)	**2,3678**	**Disp. (m3)**	**5,80004**	**/ Disp. (m3)**	**5,80003**	Hull Mom(m4)	1,586
Trim (°)	**-0,207**	**Xc heel (m)**	**4,427**	**/ Xg (m)**	**4,427**	Mom(kN.m)	15,95
		Other results		Xc Heel 0°	4,466	**Yg heel (m)**	**-0,037**
		Yc heel (m)	**-0,273**	Yc Heel 0°	0,000	**>> GZ (m)**	**0,236**
		Zc heel (m)	**-0,218**	Zc Heel 0°	-0,218	**RM (kN.m)**	**13,77**
		Sw heel (m2)	**29,26**	Sw Heel 0°	29,35	**Obliquity (°)**	**3,56**

Heel = 20°

Data to enter		Results for iteration on height and trim		Data to compare with :		Other results for RM and obliquity	
Heel (°)	20,0			Mass (kg)	5945,04		
Height (cm)	9,3222	Disp. (m3)	5,80003	/ Disp. (m3)	5,80003	Hull Mom(m4)	2,853
Trim (°)	-1,110	Xc heel (m)	4,427	/ Xg (m)	4,427	Mom(kN.m)	28,68
		Other results		Xc Heel 0°	4,466	Yg heel (m)	-0,074
		Yc heel (m)	-0,492	Yc Heel 0°	0,000	>> GZ (m)	0,418
		Zc heel (m)	-0,225	Zc Heel 0°	-0,218	RM (kN.m)	24,39
		Sw heel (m2)	28,27	Sw Heel 0°	29,35	Obliquity (°)	6,12

Heel 30°

Data to enter		Results for iteration on height and trim		Data to compare with :		Other results for RM and obliquity	
Heel (°)	30,0			Mass (kg)	5945,04		
Height (cm)	21,3438	Disp. (m3)	5,80003	/ Disp. (m3)	5,80003	Hull Mom(m4)	3,670
Trim (°)	-2,442	Xc heel (m)	4,427	/ Xg (m)	4,427	Mom(kN.m)	36,90
		Other results		Xc Heel 0°	4,466	Yg heel (m)	-0,107
		Yc heel (m)	-0,633	Yc Heel 0°	0,000	>> GZ (m)	0,525
		Zc heel (m)	-0,231	Zc Heel 0°	-0,218	RM (kN.m)	30,63
		Sw heel (m2)	26,05	Sw Heel 0°	29,35	Obliquity (°)	7,89

Comparison of the 2 versions concerning Sw and RM :

Heel (°)	Tut 34	Tut 34 HC
10	Sw : 28,57 m2 RM : 10,63 kN.m	Sw : 29,26 m2 >> +2,4 % RM : 13,77 kN.m >> +29,5 %
20	Sw :27,91 m2 RM : 19,48 kN.m	Sw : 28,27 m2 >> +1,3 % RM : 24,39 kN.m >> +25,2 %
30	Sw : 27,23 m2 RM : 25,55 kN.m	Sw : 26,05 m2 >> -4,3 % RM : 30,63 kN.m >> +19,9 %

>>> The second version is significantly better :

- significant increase of the righting moment RM
- at the cost of a very little increase of the wetted surface Sw, +2,5 % at Heel 0° to +2,4% at Heel 10°, which is moreover be partly compensated by the 2% increase of the sailplan.

One can now summarize this final version Tut 34 HC, input and ouput data

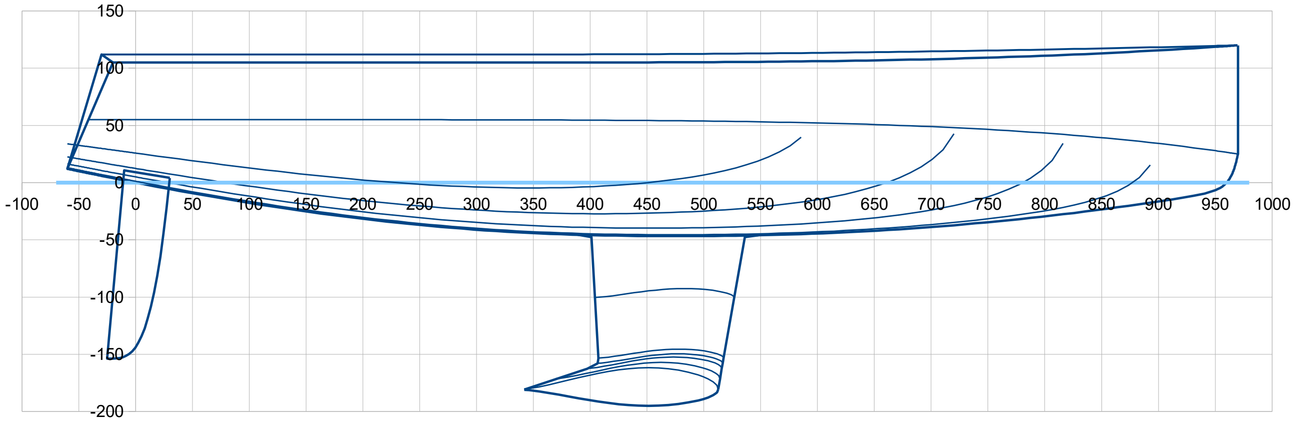
Part 3 : summarize of the final version « Tut 34 HC »

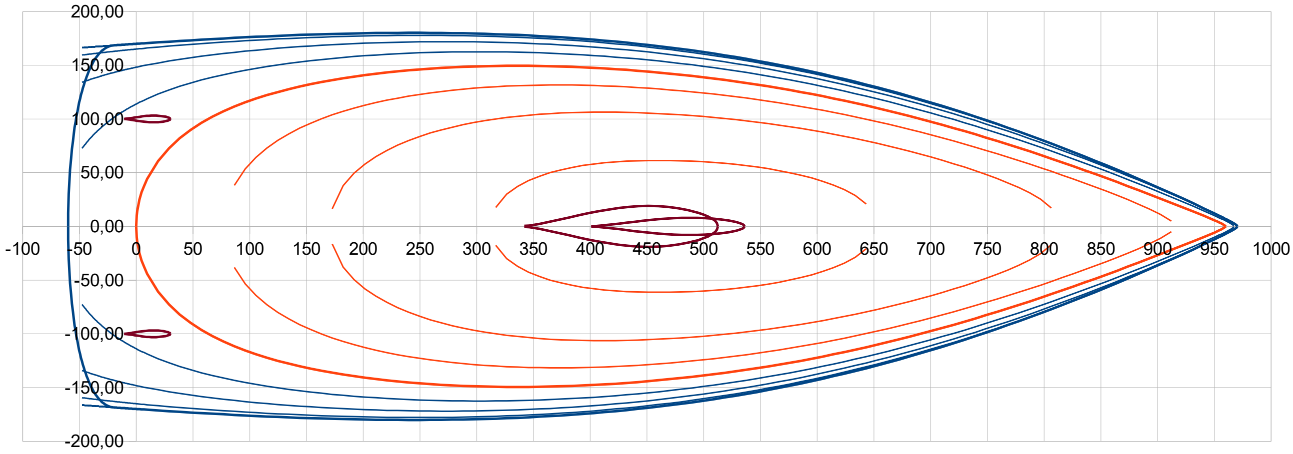
Gene-Hull input data :

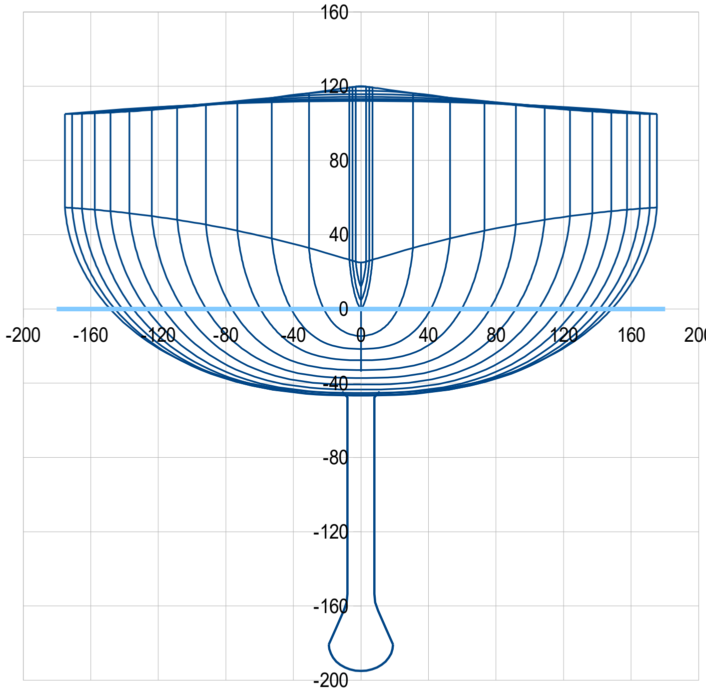
1.1 Hull data	metric
Lenght of waterline :	
Lwl (m)	9,60
Maximum draft of the hull bo	
Tc (m)	0,467
X Tc (%Lwl)	50,00
Hull bow :	
Xbow (m)	9,70
Zbow (m)	1,20
Shape coefficient of the bow	
Cet	60
Polynomials of the keel line,	
Pui q av	2,10
Pui q ar	2,40
Rear end of the transom :	
X tab ar (m)	-0,60
Z tab ar (m)	0,120
Sheer line, in horizontal proj	
Bg (m)	0,890
X Bg (% Lwl)	65,0
Alfa (°)	15,070
Pui liv y	2,00
Cor Pui liv	0,020
Pui Cor Pui	1,25
X liv ar (m)	-0,20
Scow	0,03
Option Hard Chine line, in ve	
Type	1
1,2 Zhc av (m)	0,25
2 Zhc m (m)	0,38
1,2 Zhc ar (m)	0,55
Pui hc z	5
Sheer line, in vertical project	
Z liv m (m)	1,05
Z liv ar (m)	1,05
Pui liv z	3
Deck / central line rear end	
Z p m (m)	1,12
X p ar (m)	-0,30
Z p ar (m)	1,12
Pui deck z	2,0
Sections : as a combination	
Sections U :	
C Hu av	0,19
C Hu ar	0,46
Pui Hu	0,80
Pui U av	8,00
Pui U ar	8,00
Pui Pui U	4,00
Cor Pui Pui U	0,00
Sections E and combination	
Pui E	2,00
mix UE av	0,60
mix UE ar	0,00
Pui mix UE	1,00

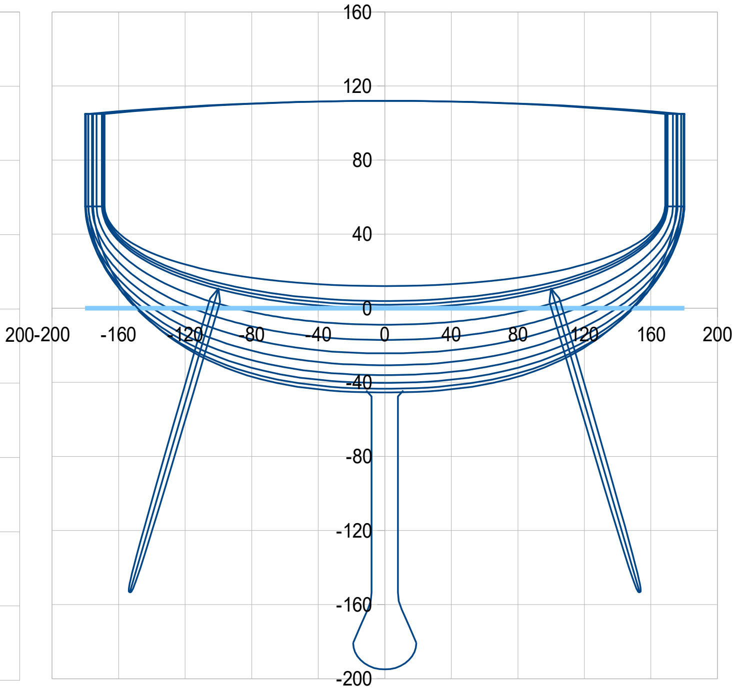
1.2 Keel data	
Xq ar (m)	4,01
C root (m)	1,35
C tip (m)	1,10
Th keel(cm)	16,00
F angle (°)	80,00
C bulb (m)	1,75
Th bulb(cm)	38,00
Draft oa (m)	1,95
naca 00xx	0
naca 63-0xx	1
naca 65-0xx	0
Density keel	7,30
Density bulb	11,35
1.3 Rudder data	
Xr ar (m)	-0,10
C root (m)	0,40
t/c (%)	15,00
R angle (°)	85,00
L ar (m)	1,73
C roundness	3,50
naca 00xx	0
naca 63-0xx	1
naca 65-0xx	0
Nb of rudders	2
Offset y (m)	1,00
Angle (°)	18,0

>>> Gene-Hull output data / the 2D linesplan :









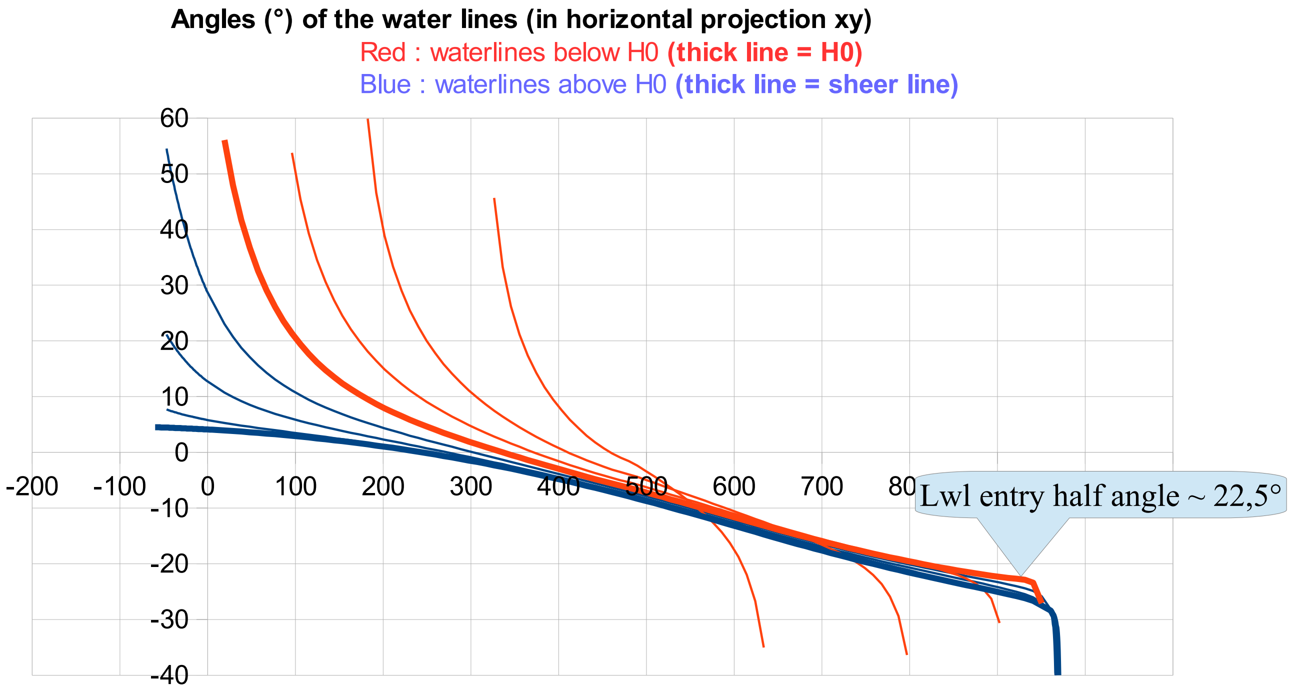
>>> one can note that the hard chine, i.e. the transition between the vertical and the round shapes of the sections, is actually very soft although it affects the whole volume and characteristics.

>>> Gene-Hull output / hydrostatics data :

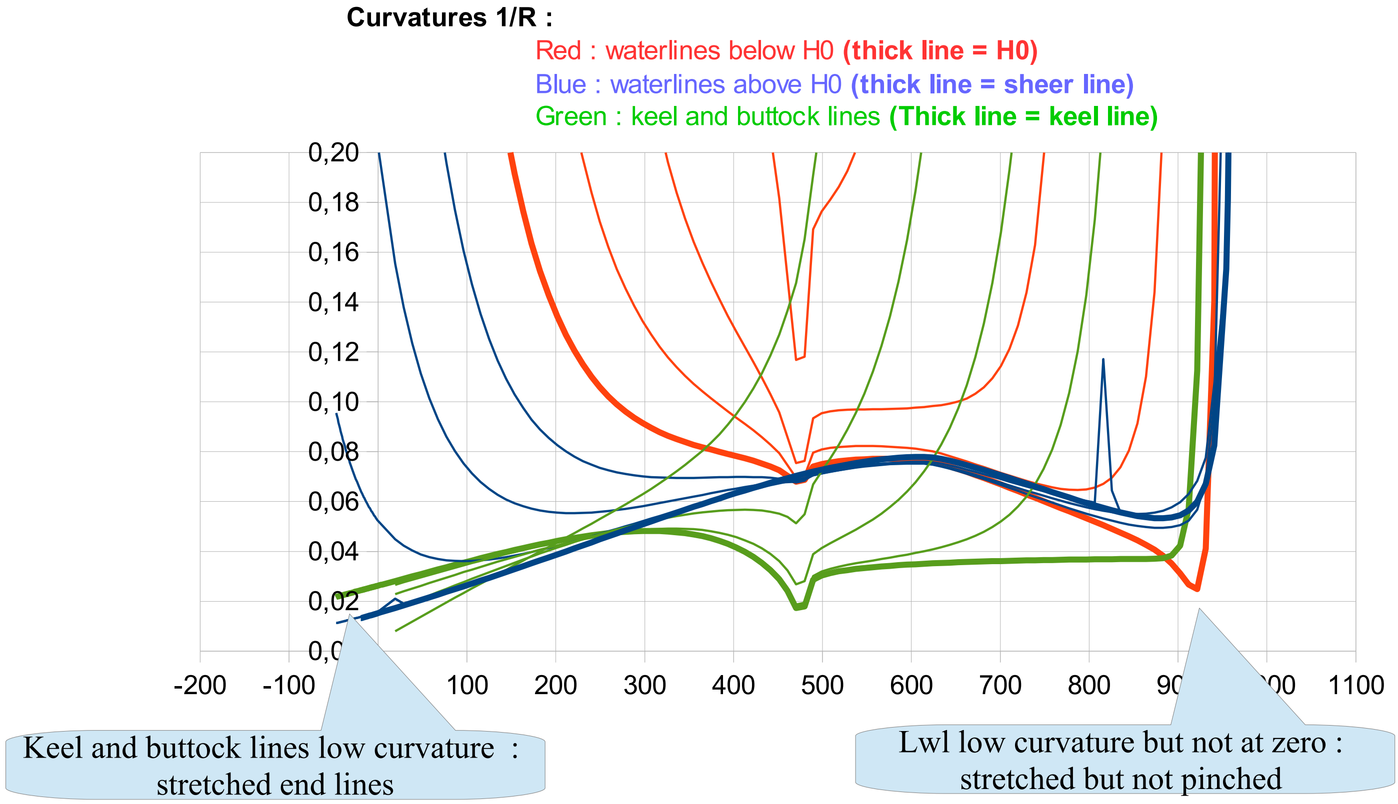
2.1 Hull															
Loa (m)	10,30			Lwl (m)	9,60										
>> ft	33,79				31,50										
B (m)	3,60			at X (% Lwl)	25,0										
>> ft	11,82														
Bwl (m)	2,99			at X (% Lwl)	35,0			> Bwl/B	0,830						
>> ft	9,81									Freeboards (m) >	Aft		Midship		Fore
Tc (m)	0,467			at X (%Lwl)	50,0						1,05		1,05		1,20
>> ft	1,53									>> ft	3,44		3,44		3,94
		Displacement at H0 (m3)	5,52578			at Xc (m)	4,491			Xc (%Lwl)	46,79			Zc (m)	-0,168
		>> lbs	12487			w. seawater	1025		kg/m3					>> ft	-0,55
Disp at H(cm)	-3,00		4,92349			at Xc (m)	4,525			Xc (%Lwl)	47,14			Zc (m)	-0,157
Disp at H(cm)	3,00		6,15535			at Xc (m)	4,456			Xc (%Lwl)	46,41			Zc (m)	-0,180
Cp (%)	57,48														
Sf (m2)	20,65			at Xf (m)	4,165			Xf (%Lwl)	43,38					>>> Xc – Xf (%Lwl)	3,40
>> ft2	222,28			>> ft	13,66										
		Angle immersed sheer Ii (°)	30,9	at section C4 (40% Lwl)											
Sw (m2)	22,05			>Sm/D^(2/3)	7,05										
>> ft2	237,33														
Shull (m2)	47,29			at X (m)	4,257			Z (m)	0,124						
>> ft2	509,00			>> ft	13,97			>> ft	0,41						
Sdeck (m2)	27,31			at X (m)	3,823										
>> ft2	293,94			>> ft	12,54										
2.2 Keel															
Vol. keel (m3)	0,13410			at X (m)	4,754			X (%Lwl)	49,52			Z (m)	-0,979		
Mass keel(kg)	978,94			>> ft	15,60							>> ft	-3,21		
>> lbs	2158														
Vol. Bulb(m3)	0,09884			at X (m)	4,520			X (%Lwl)	47,08			Z (m)	-1,766		
Mass bulb(kg)	1121,83			>> ft	14,83							>> ft	-5,79		
>> lbs	2473														
Draft oa (m)	1,95					Sw (m2)	4,80					Sxz (m2)	1,71		
>> ft	6,40					>> ft2	51,63					>> ft2	18,35		
CLR (m)	4,98			CLR (%Lwl)	51,83	CLR = Center of Lateral Resistance									
>> ft2	53,56	method : keel profile extended to the waterline, LCR at 25% chord and 45% draft oa													
2.3 Rudder(s)															
Number	2														
Volume (m3)	0,04213			at X (m)	0,050			X (%Lwl)	0,53			Z (m)	-0,648		
Sw (m2)	2,51			>> ft	0,17							Sxz (m2)	0,60		per rudder
>> ft2	26,97											>> ft2	6,48		
2.4 Hull + Keel + Rudder(s)															
		Displacement at H0 (m3)	5,80086			at Xc (m)	4,466			Xc (%Lwl)	46,52			Zc (m)	-0,218
		Displacement at H0 (kg)	5946			>> ft	14,65							>> ft	-0,71
		>> lbs	13108												
		Ballast (kg)	2101			at Xg (m)	4,629			Xg (%Lwl)	48,22			Zg (m)	-1,399
		>> lbs	4631			>> ft	15,19							>> ft	-4,59
		>> % Ballast	35,3												
		Sw (m2)	29,35			>Sw/D^(2/3)	9,09			Lwl/D^(1/3)	5,34				
		>> ft2	315,93							DLR	187			M(lbs/2240)/(Lwl(ft)/100)^3	
2.5 Data from the mass spreadsheet															
Light boat:		M (kg)	5945			at Xg (m)	4,427							at Zg (m)	0,215

>>> One can note that the Bwl/B ratio is finally 0,83 , instead of 0,77 for the first version.

>>> **Gene-Hull output / angles and curvatures :**



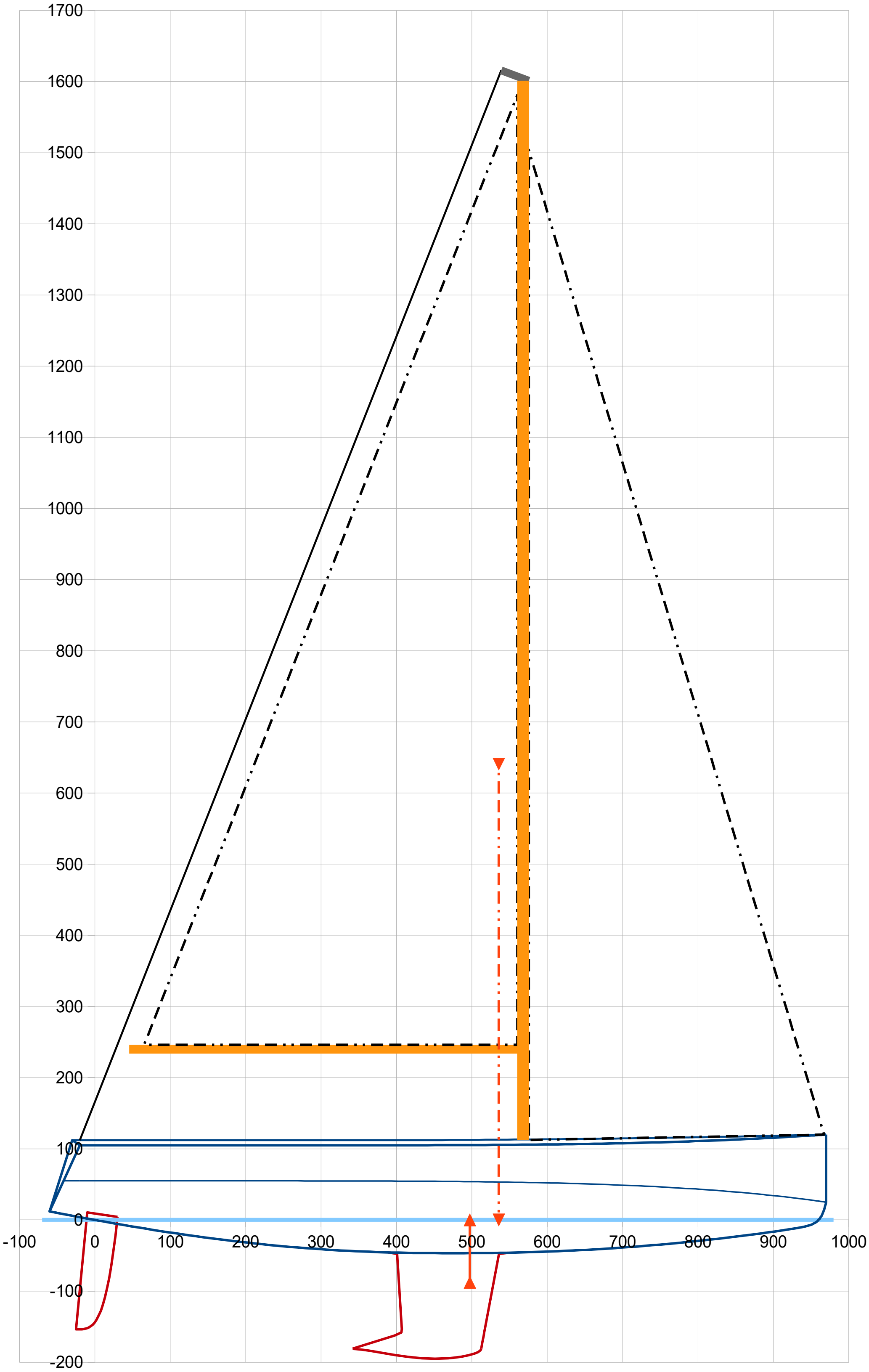
>>> One can note that the entry half angle has increased to 22,5° but is still in the usual range.



>>> The sailplan input and ouput data

Data to enter		*>> in feet*
Xmast (m)	**5,68**	*18,64*
Zboom(m)	**2,40**	*7,87*
I (m)	**13,90**	*45,60*
J (m)	**3,92**	*12,86*
P (m)	**13,35**	*43,80*
E (m)	**4,95**	*16,24*

Results for the Sailplan (i.e. Fore + Main triangles)				
Geometrical center				
Xv (m)	5,359	Zv (m)	6,407	
Surface triangles St (m2)	**60,29**	*648,91*	*sqft*	
>> St / Sw	2,05	*PYD : 2 to 2,5, average 2,25*		
>> St / D^(2/3)	18,67	*PYD : 15 to 22, average 19*		
>> Skeel / St (%)	2,83	*PYD : ~ 2,75% (racing) to ~ 3,5 % (racing/cruising)*		
>> Srudder / St (%)	1,00	*PYD : 1 to 2, average 1,4%*		
Lead (Xv – CLR) (% Lwl)	**4,0**	*PYD : 3 to 7 (fractional rig), 5 to 9 (masthead)*		



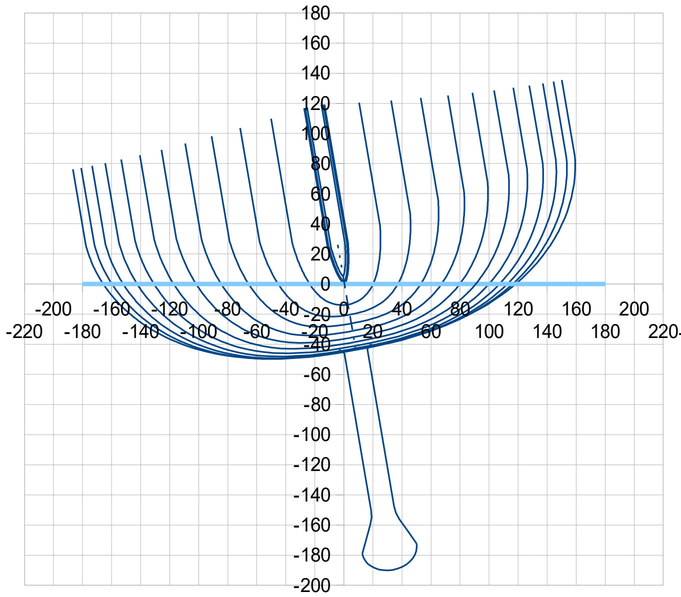
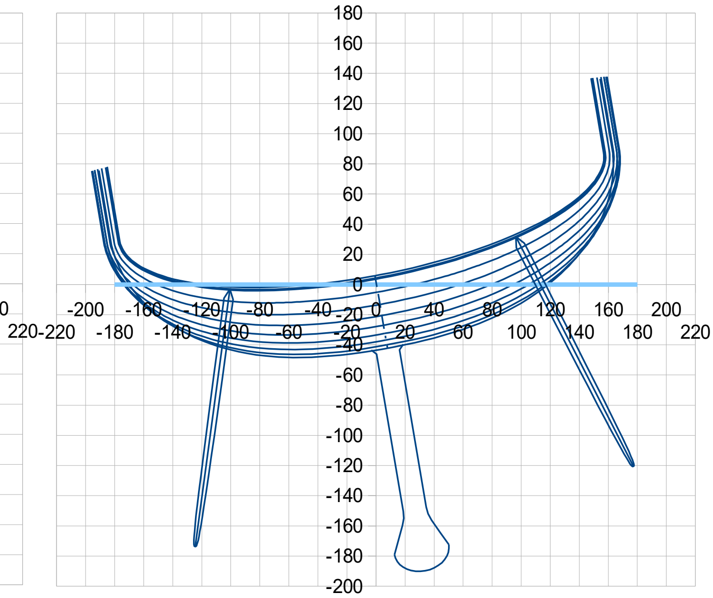
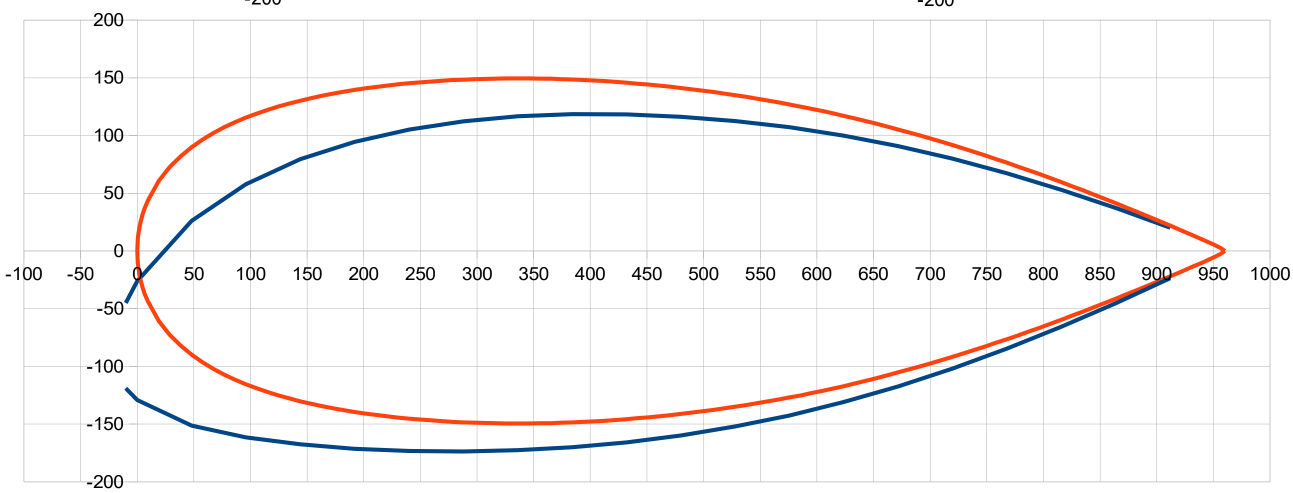
>>> Mass spreadsheet / input and output data :

Mass and Xg, Zg position – early stage estimation Data from Gene-Hull sheet are in blue **Data to enter are in bold black** (inc. default value to initiate)	Input data L or S or V m or m2 or m3	 mass unit or % Disp.	Results Mass (kg)	 Xg (m)	 M Xg	 Zg (m)	 M Zg
Hull (skin, structure, keel interface) *, with S, Xs and Zs from Gene-Hull sheet*	47,29	**24,00** (kg/m2)	1134,90	4,26	4830,80	0,01	6,62
Deck – roof – cockpit (skin and structure) *, with S, Xs and Zs from Gene-Hull sheet*	27,31	**18,00** (kg/m2)	491,55	3,82	1879,29	1,12	550,54
Rig, sails and deck fittings		**12,00** (% Disp.)	713,51	**5,25**	3745,90	**4,80**	3424,83
Cabin accomodation and motor		**24,00** (% Disp.)	1427,01	**4,30**	6136,15	**0,20**	285,40
Keel			2100,77	4,63	9724,50	-1,40	-2939,33
Rudder		**1,30** (% Disp.)	77,30	0,05	3,90	-0,65	-50,11
		Results : Light weight boat >>>	5945,04	4,427	26320,54	0,215	1277,94

>>> Gene-Hull / Hull with heel :

Heel 10° :

Data to enter		Results for iteration on height and trim		Data to compare with :		Other results for RM and obliquity	
Heel (°)	10,0	Disp. (m3)	5,80004	Mass (kg)	5945,04	Hull Mom(m4)	1,586
Height (cm)	2,3678	Xc heel (m)	4,427	/ Disp. (m3)	5,80003	Mom(kN.m)	15,95
Trim (°)	-0,207	**Other results**		/ Xg (m)	4,427	Yg heel (m)	-0,037
		Yc heel (m)	-0,273	Xc Heel 0°	4,466	>> GZ (m)	0,236
		Zc heel (m)	-0,218	Yc Heel 0°	0,000	RM (kN.m)	13,77
		Sw heel (m2)	29,26	Zc Heel 0°	-0,218	Obliquity (°)	3,56
				Sw Heel 0°	29,35		

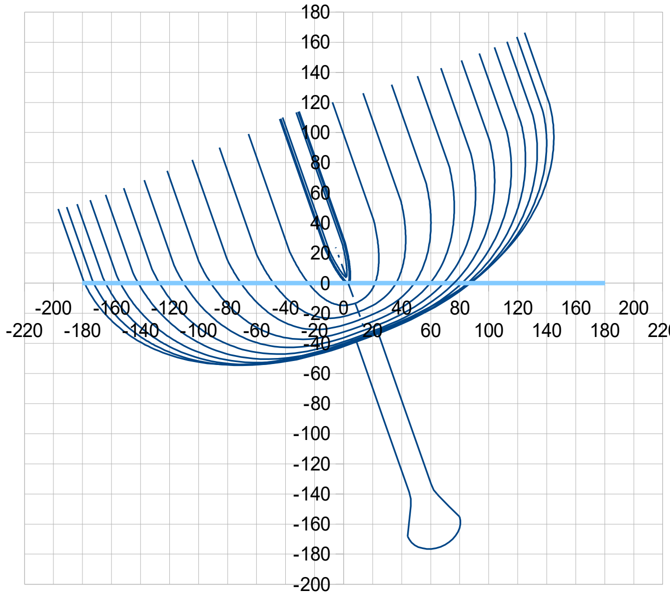
Heel 20°

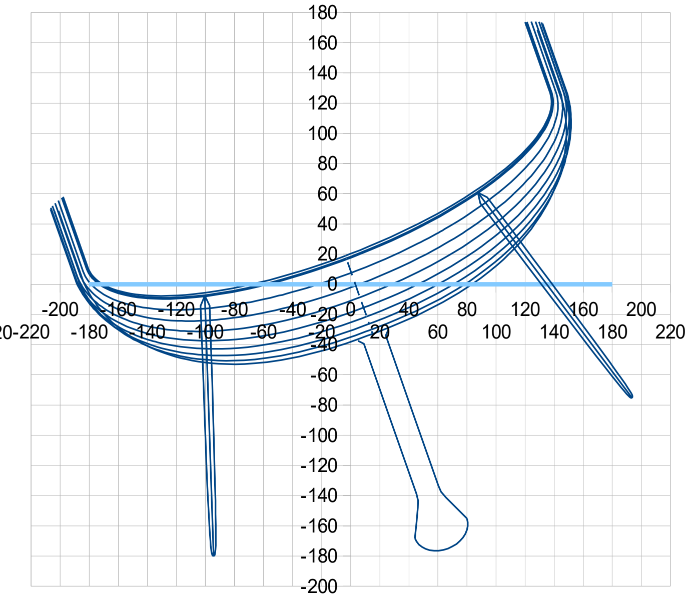
Data to enter	
Heel (°)	20,0
Height (cm)	9,3222
Trim (°)	-1,110

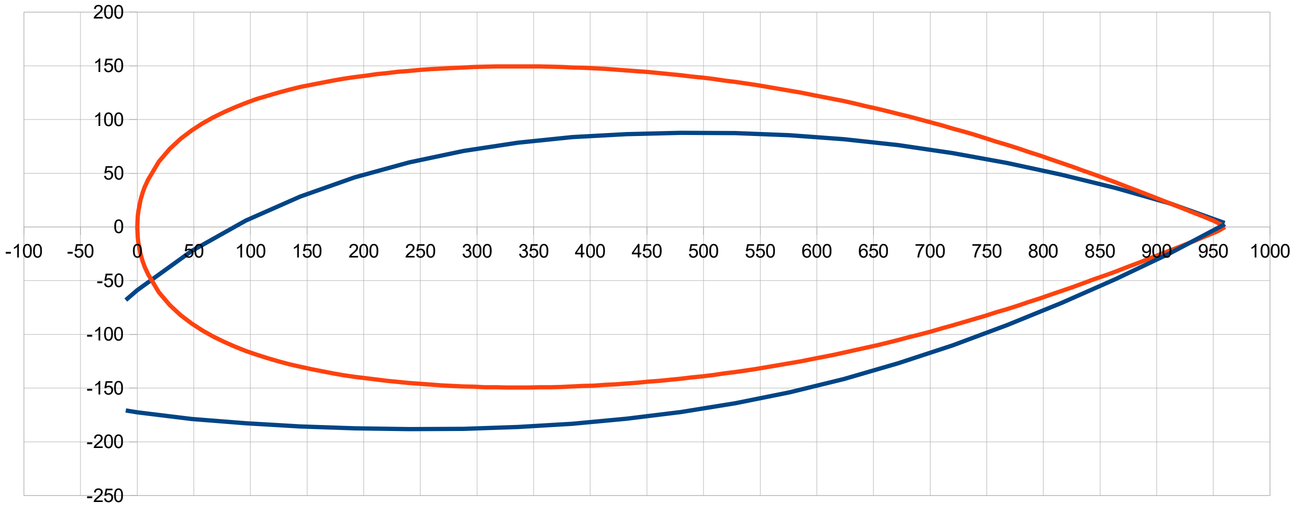
Results for iteration on height and trim	
Disp. (m3)	5,80003
Xc heel (m)	4,427
Other results	
Yc heel (m)	-0,492
Zc heel (m)	-0,225
Sw heel (m2)	28,27

Data to compare with :	
Mass (kg)	5945,04
/ Disp. (m3)	5,80003
/ Xg (m)	4,427
Xc Heel 0°	4,466
Yc Heel 0°	0,000
Zc Heel 0°	-0,218
Sw Heel 0°	29,35

Other results for RM and obliquity	
Hull Mom(m4)	2,853
Mom(kN.m)	28,68
Yg heel (m)	-0,074
>> GZ (m)	0,418
RM (kN.m)	24,39
Obliquity (°)	6,12

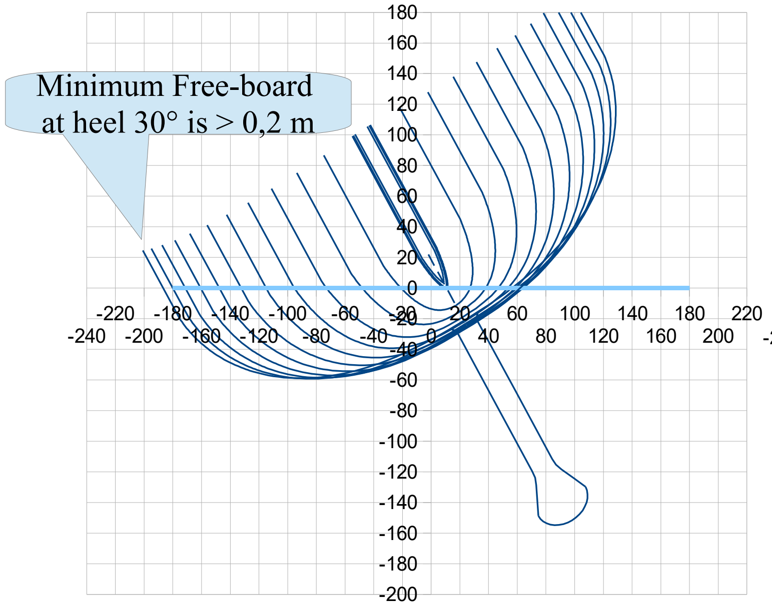


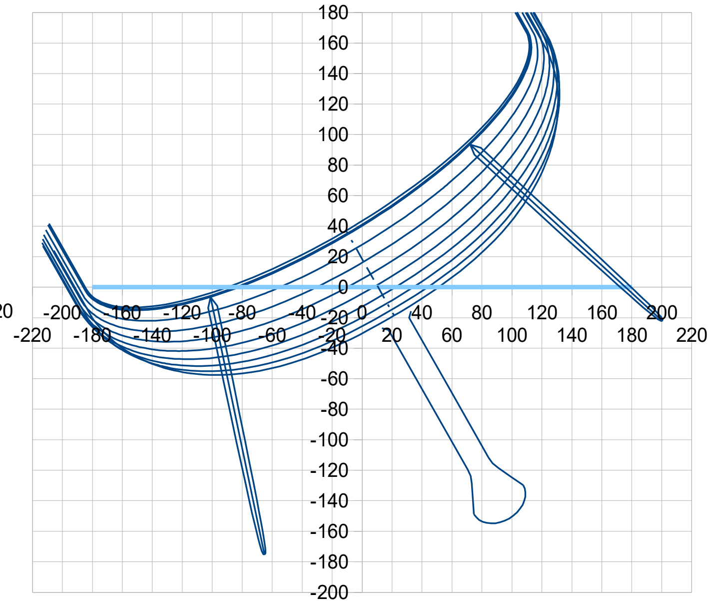


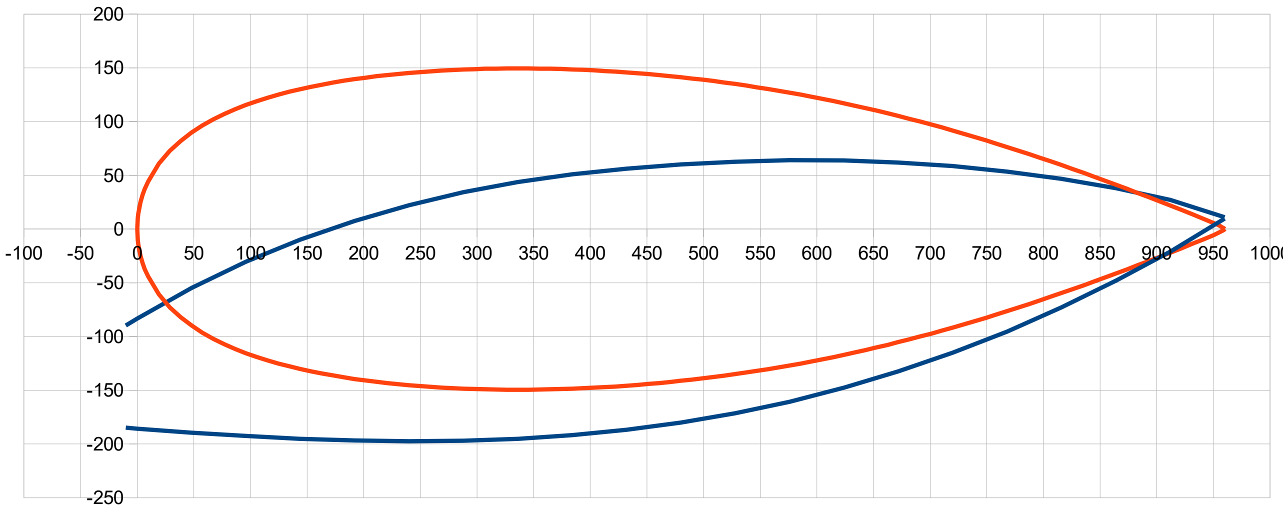


Heel 30°

Data to enter		Results for iteration on height and trim		Data to compare with :		Other results for RM and obliquity	
Heel (°)	30,0			Mass (kg)	5945,04		
Height (cm)	21,3438	Disp. (m3)	5,80003	/ Disp. (m3)	5,80003	Hull Mom(m4)	3,670
Trim (°)	-2,442	Xc heel (m)	4,427	/ Xg (m)	4,427	Mom(kN.m)	36,90
		Other results		Xc Heel 0°	4,466	Yg heel (m)	-0,107
		Yc heel (m)	-0,633	Yc Heel 0°	0,000	>> GZ (m)	0,525
		Zc heel (m)	-0,231	Zc Heel 0°	-0,218	RM (kN.m)	30,63
		Sw heel (m2)	26,05	Sw Heel 0°	29,35	Obliquity (°)	7,89







Conclusion :

By hoping this approach dtailed step by step can help the data input and guide the iterations.
Of course, there is a lot of other possible variants and paths towards a balanced design.
And an early stage design is itself the starting basis for the detailed engineering stage, and further iterations can be then necessary.