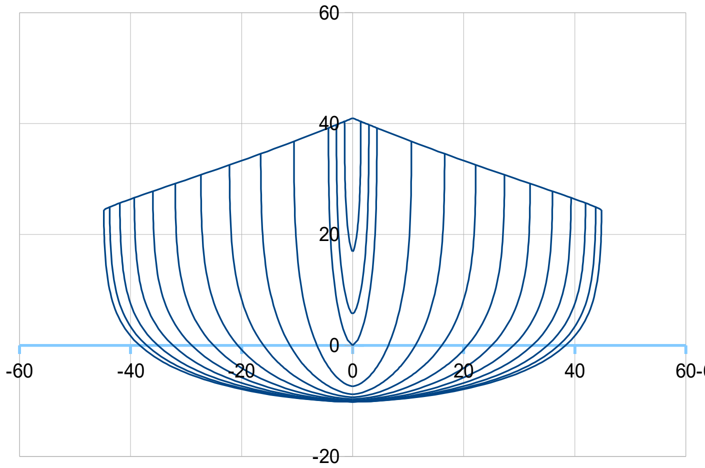
2019 11 29

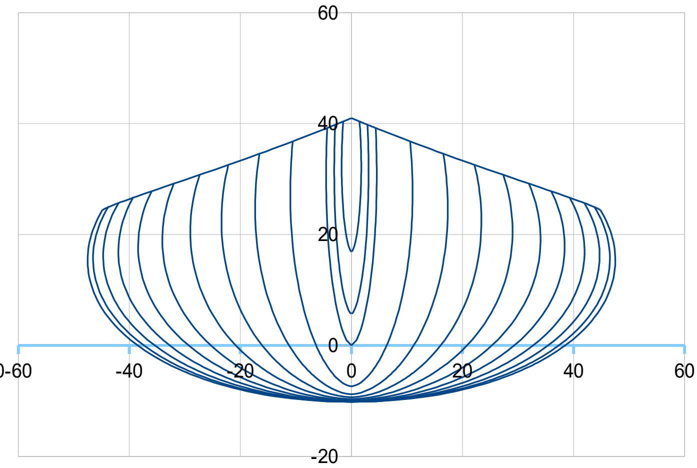
Tandem Canoe : two examples with Gene-Hull VE Canoe 2.4

The use of Gene-Hull VE Canoe, in its upgraded version 2.4, is illustrated through the generation of 2 similar hulls for a typical Tandem Canoe project, one without and one with tumblehome shape, named respectively C1 and C2 in the following. The two versions share the same keel line and sheer line, so consequently same Length overall (Loa 5,43 m (17,81 ft)), same maximum beam of the sheer line (Bsheer 0,90 m (35,5'')), same free-boards (sheer to keel line). The tumblehome option is usually considered relevant for a canoe design, because offering both a better paddling ergonomy, a greater stability and compliance with a heavy loading.

C1



C2



With using the subroutines « Hull stability with various loading » and « VPP », a comparison of the 2 versions as regard the stablity and the performance issues is done for an usual range of the loading, 70 kg to 270 kg (154 lbs to 595 lbs) i.e. from two light kids to two heavy men with equipment, in order to highlight on the tumblehome influence through direct comparisons.

Summary :

1 Presentation of the 2 hulls, drawn with the same draft Tc = 0,102 m (4'')

2 The stability issue

The initial stability
The righting capacity

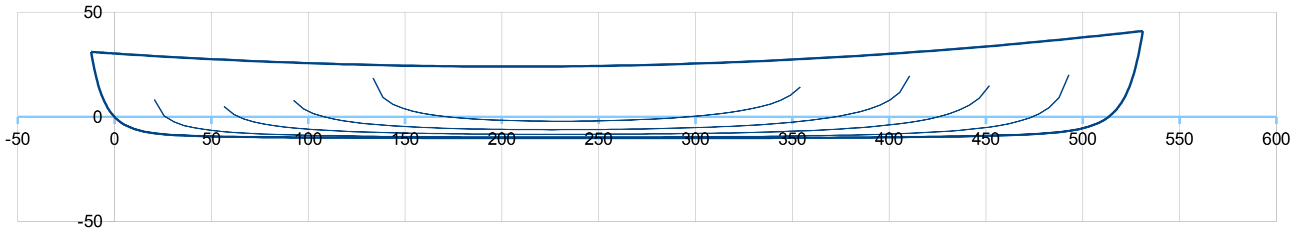
3 The performance issue : estimation of the drag and of the speed potential

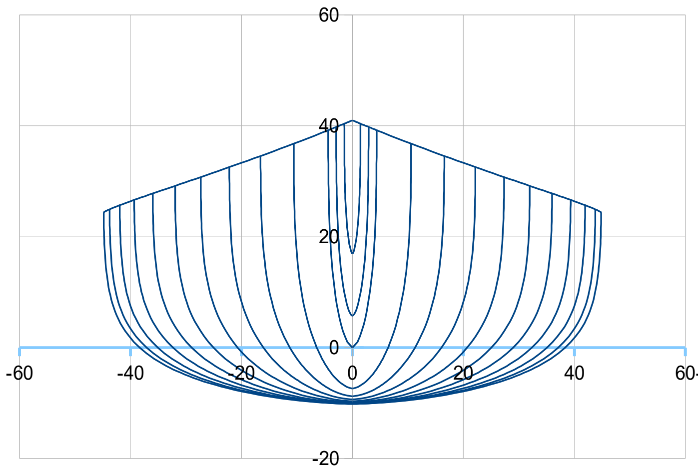
Lwl, Bwl and draft evolution with the loading
Wetted surface Sw evolution with the loading
Tentative estimation in terms of drag and speed
Conclusion on the performance estimation and C1/C2 comparison

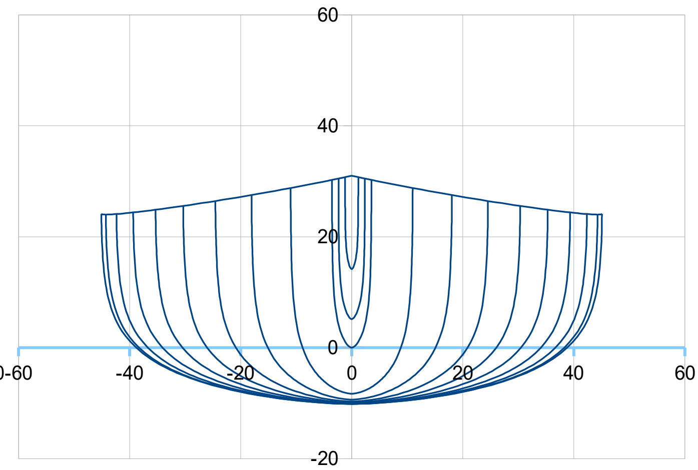
1. Presentation of the 2 hulls, drawn with the same draft Tc = 0,102 m (4'')

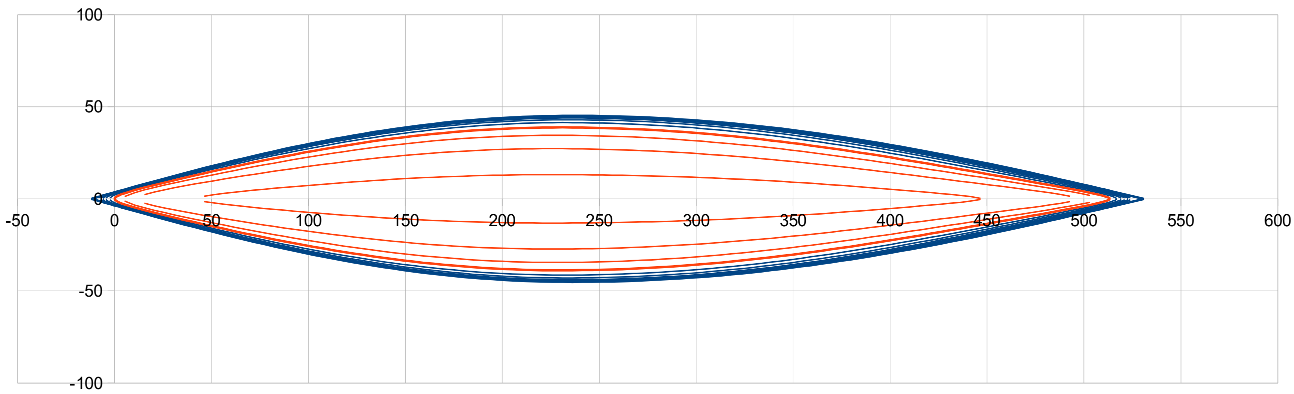
Hull C1 without tumblehome

Loa : 5,43 m (17,81 ft) ; Lwl : 5,13 m (16,84 ft) ; Bsheer : 0,90 m (35,5'') = Boa (no tumblehome)
Bwl : 0,776 m (30,56'') ; **Tc : 0,102 m (4'')** ; Displacement : 178,8 kg (394,2 lbs)



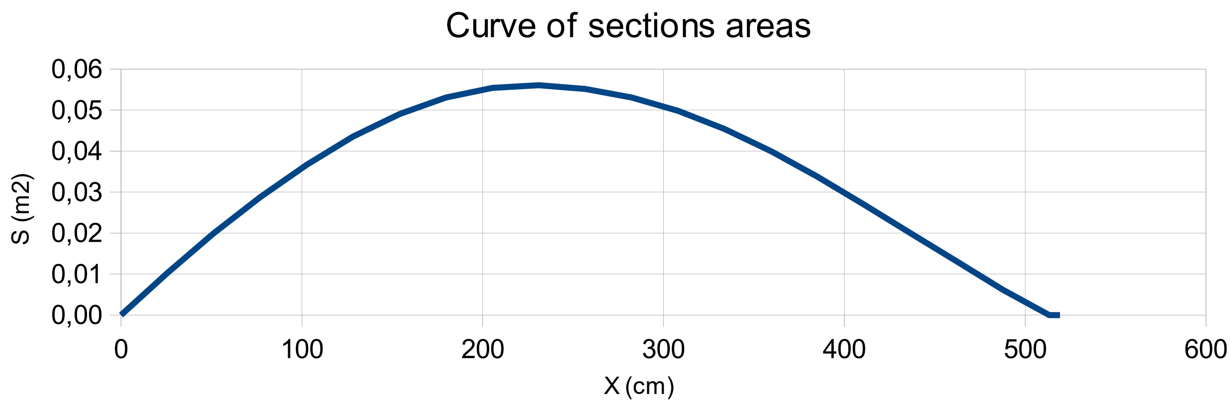






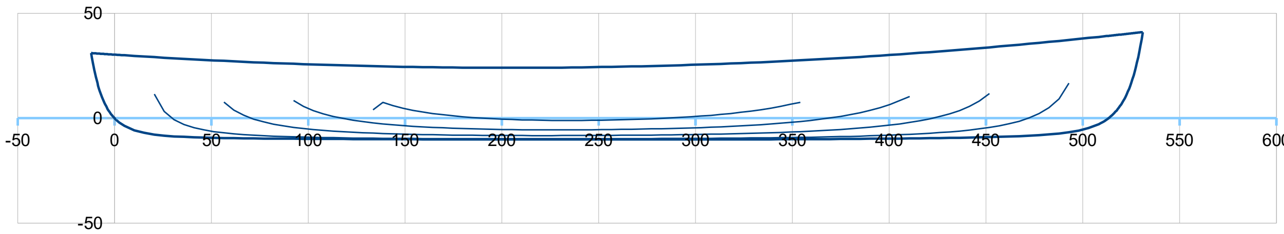
C1 Hydrostatics data with the floatation line at draft 4'' :

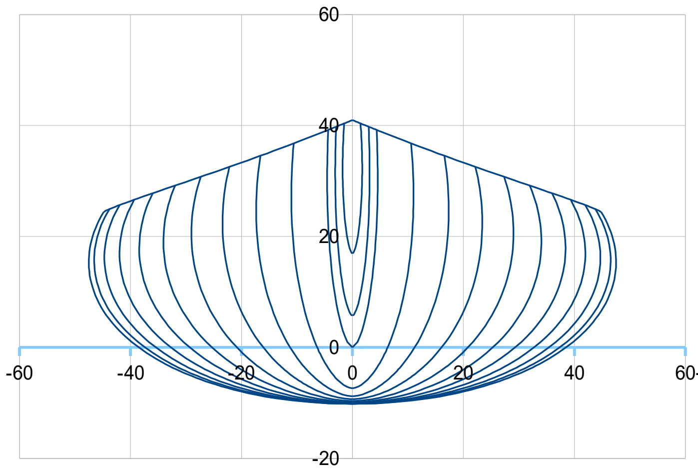
Hull								
Loa (m)	**5,43**	**Lwl (m)**	**5,13**	> Lwl/D^(1/3)	9,11			
>> ft	***17,81***	***>> ft***	***16,84***	*DLR*	*37*	*M(lbs/2240)/(Lwl(ft)/100)^3*		
Bsheer (m)	**0,90**	**at X (% Lwl)**	**46,0**	**Bmax (m)**	**0,90**			
>> inch	***35,50***			***>> inch***	***35,48***	> Lwl / Bwl	6,61	
Bwl (m)	**0,776**	**at X (% Lwl)**	**45,0**	> Bwl / B	0,861	> Bwl / Lwl	0,15118	
>> inch	***30,56***			**Freeboards (m) >**		**Aft**	**Midship**	**Fore**
Tc (m)	**0,102**	**at X (%Lwl)**	**50**	> Bwl / Tc	7,64	**0,31**	**0,24**	**0,41**
>> inch	***4,00***				***>> inch***	***12,20***	***9,45***	***16,14***
Displacement at H0 (m3)	**0,17878**	**at Xc (m)**	**2,444**		**Xc (%Lwl)**	**47,61**	**Zc (m)**	**-0,040**
(kg)	**178,8**	*>> ft*	*8,02*				*>> inch*	*-1,58*
>> lbs	***394,2***	*with water mass / vol. of*			*1000*	*kg/m3*		
Cp (%)	**62,13**							
Sf (m2)	**2,58**	**at Xf (m)**	**2,469**	**Xf (%Lwl)**	**48,10**		>>> Xc – Xf (%Lwl)	-0,49
>> ft2	*27,78*	*>> ft*	*8,10*					
Angle immersed sheer Ii (°)	**28,5**	at section C4 (40% Lwl)						
Sw (m2)	**2,83**	>Sw/D^(2/3)	8,91					
>> ft2	*30,44*							
Shull (m2)	**5,93**	**at X (m)**	**2,608**	**Z (m)**	**0,041**			
>> ft2	*63,88*	*>> ft*	*8,56*	*>> inch*	*1,60*			

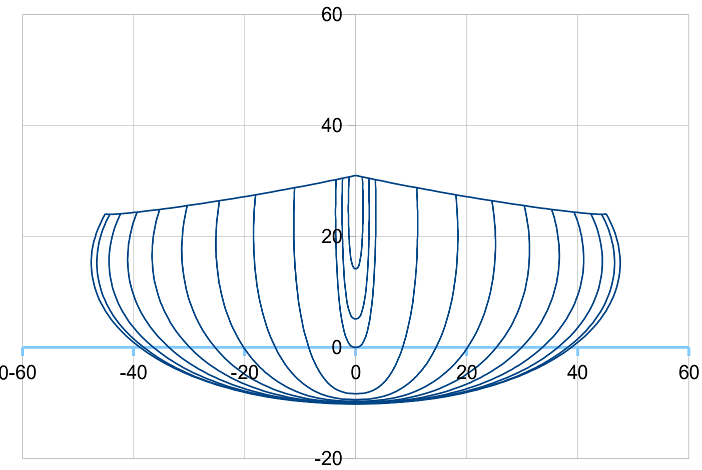


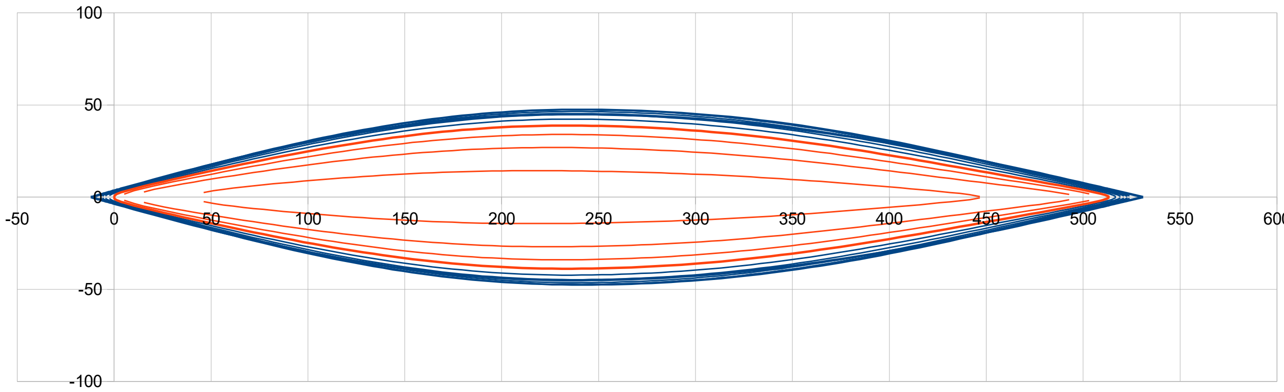
Hull C2 with tumblehome

Loa : 5,43 m (17,81 ft) ; Lwl : 5,13 m (16,84 ft) ; Bsheer : 0,90 m (35,5'') ; Boa : 0,95 m (37,5'')
Bwl : 0,777 m (30,59'') ; **Tc : 0,102 m (4'')** ; Displacement : 178,7 kg (394 lbs)



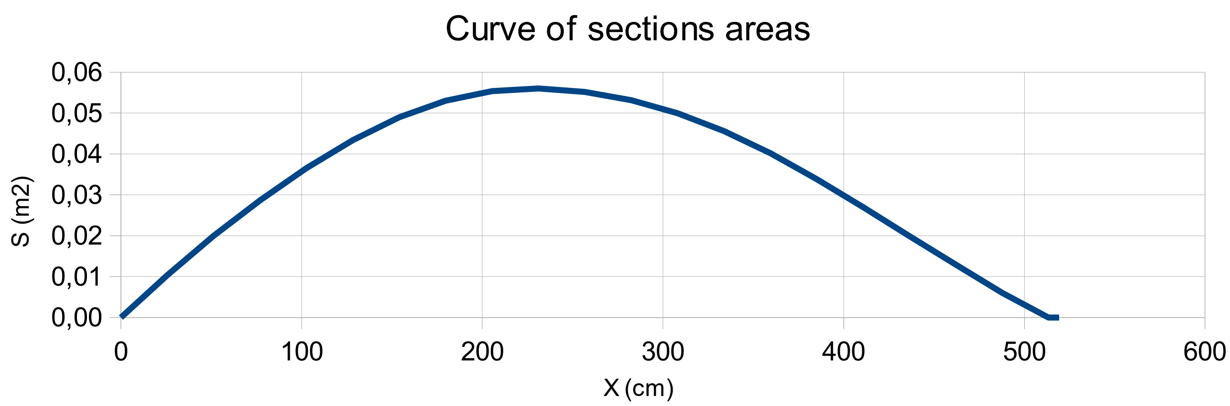






C2 Hydrostatics data with the floatation line at draft 4'' :

Hull								
Loa (m)	**5,43**	**Lwl (m)**	**5,13**	> Lwl/D^(1/3)	9,11			
>> ft	***17,81***	***>> ft***	***16,84***	*DLR*	*37*	*M(lbs/2240)/(Lwl(ft)/100)^3*		
Bsheer (m)	**0,90**	**at X (% Lwl)**	**46,0**	**Bmax (m)**	**0,95**			
>> inch	***35,50***			***>> inch***	***37,49***	> Lwl / Bwl	6,61	
Bwl (m)	**0,777**	**at X (% Lwl)**	**45,0**	> Bwl / B	0,861	> Bwl / Lwl	0,15130	
>> inch	***30,58***			**Freeboards (m) >**		**Aft**	**Midship**	**Fore**
Tc (m)	**0,102**	**at X (%Lwl)**	**50**	> Bwl / Tc	7,65	**0,31**	**0,24**	**0,41**
>> inch	***4,00***				***>> inch***	***12,20***	***9,45***	***16,14***
Displacement at H0 (m3)	**0,17870**	**at Xc (m)**	**2,445**	**Xc (%Lwl)**	**47,62**		**Zc (m)**	**-0,041**
(kg)	**178,7**	*>> ft*	*8,02*				*>> inch*	*-1,60*
>> lbs	***394,0***	*with water mass / vol. of*	*1000*	*kg/m3*				
Cp (%)	**62,14**							
Sf (m2)	**2,57**	**at Xf (m)**	**2,483**	**Xf (%Lwl)**	**48,36**	>>> Xc – Xf (%Lwl)		-0,74
>> ft2	*27,67*	*>> ft*	*8,15*					
Angle immersed sheer Ii (°)	**28,5**	at section C4 (40% Lwl)						
Sw (m2)	**2,82**	>Sw/D^(2/3)	8,89					
>> ft2	*30,36*							
Shull (m2)	**6,04**	**at X (m)**	**2,612**	**Z (m)**	**0,041**			
>> ft2	*65,00*	*>> ft*	*8,57*	*>> inch*	*1,63*			



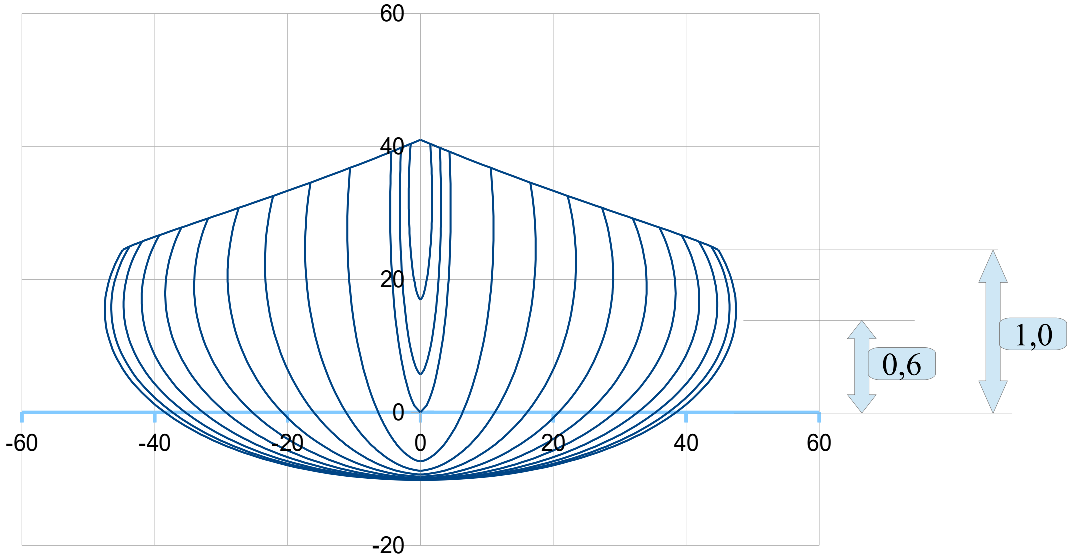
Comments on the Gene-Hull input data to obtain these 2 versions :

	C1	C2
Lenght of waterline :		
Lwl (m)	5,134	5,134
Maximum draft of the hull body :		
Tc (m)	0,1016	0,1016
Keel line front part :		
Xbow (m)	5,310	5,310
Zbow (m)	0,410	0,410
Pui q av	3,30	3,30
Cet av	10,0	10,0
Keel line, rear part :		
Xar (m)	-0,120	-0,120
Zar (m)	0,31	0,31
Pui q ar	3,30	3,30
Cet ar	10,0	10,0
Sheer line, in horizontal projection xy :		
Bmax (m)	0,9017	0,9017
at X (% Lwl)	46,0	46,0
Pui livav y	2,00	2,00
Cor Pui livav	0,030	0,030
Pui Cor Puiav	2,00	2,00
Pui livar y	2,00	2,00
Cor Pui livar	0,030	0,030
Pui Cor Puiar	2,00	2,00
Sheer line, in vertical projection xz :		
Z liv m (m)	0,240	0,240
Pui liv z	2,00	2,00
Sections : as a combination of « V » shape a		
Sections V :		
C Hv av	1,00	0,80
C Hv m	1,00	0,60
C Hv ar	1,00	0,80
Pui Hv	3,00	2,40
Pui V av	3,00	2,00
Pui V ar	6,00	2,00
Pui Pui V	2,00	2,00
Sections E and combination VE :		
Pui E1	2,00	2,90
Pui E2	5,00	5,00
mix VE av	0,50	0,50
mix VE ar	0,50	0,23
Pui mix VE	1,00	1,00

Here exactly the same input data, leading to the same keel and sheer lines

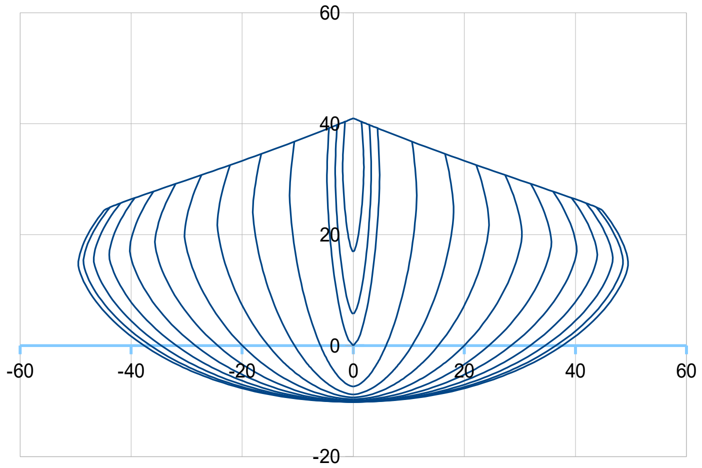
Mains parameters to introduce a tumblehome shape :
- the « C Hv » values < 1 are necessary
- better to have « Pui V av » and « Pui V ar » = 2 to have a regular « elliptical » tumblehome (recommended but not necessary, see their influence here after)

What is the meaning of a « C Hv m » = 0,6 ? >> it is ratio of the Bmax height versus the midship freeboard

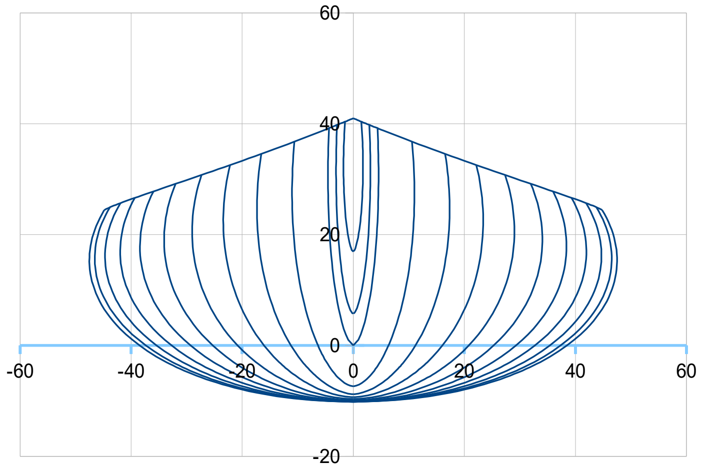


Examples of « Pui V av » and « Pui Va r » influence (all other parameters being unchanged) :

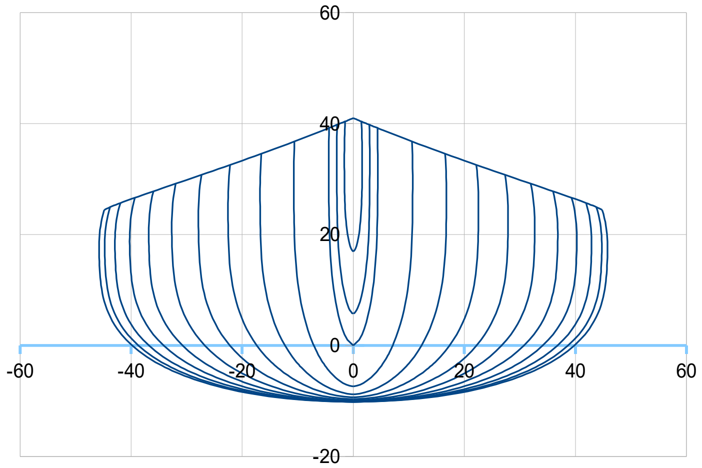
Pui Va v = Pui Var = 1,5



Pui Va v = Pui Var = 2,0 (C2 case)



Pui Va v = Pui Var = 3,0



The two hulls as drawn above share a lot of common features and figures, except the beam overall directly linked to the sections shape option (without or with tumblehome) :

	C1 (straight shape)	**C2 (tumblehome shape)**
Loa	5,43 m (17,81 ft)	5,43 m (17,81 ft)
Bmax at sheer line	0,90 m (35,5'')	0,90 m (35,5'')
At draft 4'' (Tc =0,102 m) :		
Lwl	5,13 m (16,84 ft)	5,13 m (16,84 ft)
Bwl	0,776 m (30,56'')	0,777 m (30,59'')
Displacement	178,8 kg (394,2 lbs)	178,7 kg (394 lbs)
LCB (Xc in Gene-Hull)	47,61 %Lwl	47,62 %Lwl
Cp	62,13%	62,14%
Sw	2,83 m2	2,82 m2
A small difference for the hull total surface :		
Shull	5,93 m2	6,04 m2
>>> estimated light weight (when assuming a mass unit of 4,18 kg/m2)	24,81 kg (54,70 lbs)	25,24 kg (55,64 lbs)
Xg	2,608 m	2,612 m
Zg	0,041 m	0,041 m
The maximum of the beam overall is different :		
Bmax overall	0,90 m (35,5'')	0,95 m (37,5'')

2. The stability issue

The stability is checked for the all range of loading, from 70 kg (154 lbs) typical of two kids to 270 kg (595 lbs) typical of two heavy men + camping equipment. For all the computation, this « loading » is supposed sit in the Canoe, at a center of gravity Zg = + 36 cm / H0 (i.e. in the above hull coordinates, where Z = 0 corresponds to a 4'' draft). This loading + the proper weight of the hull (as given in the table above) is so considered in the computation, within Gene-Hull that corresponds to the use of **6.1 Simplified mass spreadsheet**, examples for C1 and C2 :

C1 with load 70 kg >>> Displacement : 94,8 kg

6.1 Simplified Mass spreadsheet (Data to enter in yellow cases)

	Hull weight unit (kg/m2)	Mass (kg)	Zg (/H0) (m)	*Zg (m)*
Canoe (kg)	**4,18**	24,81	0,04	*0,076*
Load (kg)		**70,00**	**0,36**	*0,395*
	M tot (kg)	**94,8**		
	> Disp. (m3)	**0,09481**	*Zg tot (m)*	*0,311*

C1 with load 170 kg >> Displacement 194,8 kg

6.1 Simplified Mass spreadsheet (Data to enter in yellow cases)				
	Hull weight unit	Mass	Zg (/H0)	*Zg*
	(kg/m2)	(kg)	(m)	*(m)*
Canoe (kg)	**4,18**	24,81	0,04	*0,034*
Load (kg)		**170,00**	**0,36**	*0,354*
	M tot (kg)	**194,8**		
	> Disp. (m3)	**0,19481**	*Zg tot (m)*	*0,313*

C1 with load 270 kg >> Displacement 294,8 kg

6.1 Simplified Mass spreadsheet (Data to enter in yellow cases)				
	Hull weight unit	Mass	Zg (/H0)	*Zg*
	(kg/m2)	(kg)	(m)	*(m)*
Canoe (kg)	**4,18**	24,81	0,04	*-0,002*
Load (kg)		**270,00**	**0,36**	*0,317*
	M tot (kg)	**294,8**		
	> Disp. (m3)	**0,29481**	*Zg tot (m)*	*0,290*

C2 with load 70 kg >> Displacement 95,2 kg

6.1 Simplified Mass spreadsheet (Data to enter in yellow cases)				
	Hull weight unit	Mass	Zg (/H0)	*Zg*
	(kg/m2)	(kg)	(m)	*(m)*
Canoe (kg)	**4,18**	25,24	0,04	*0,077*
Load (kg)		**70,00**	**0,36**	*0,395*
	M tot (kg)	**95,2**		
	> Disp. (m3)	**0,09524**	*Zg tot (m)*	*0,311*

C2 with load 170 kg >> Displacement 195,2 kg

6.1 Simplified Mass spreadsheet (Data to enter in yellow cases)				
	Hull weight unit	Mass	Zg (/H0)	*Zg*
	(kg/m2)	(kg)	(m)	*(m)*
Canoe (kg)	**4,18**	25,24	0,04	*0,035*
Load (kg)		**170,00**	**0,36**	*0,354*
	M tot (kg)	**195,2**		
	> Disp. (m3)	**0,19524**	*Zg tot (m)*	*0,312*

C2 with load 270 kg >> Displacement 295,2 kg

6.1 Simplified Mass spreadsheet (Data to enter in yellow cases)				
	Hull weight unit	Mass	Zg (/H0)	*Zg*
	(kg/m2)	(kg)	(m)	*(m)*
Canoe (kg)	**4,18**	25,24	0,04	*-0,001*
Load (kg)		**270,00**	**0,36**	*0,318*
	M tot (kg)	**295,2**		
	> Disp. (m3)	**0,29524**	*Zg tot (m)*	*0,290*

The stability should be evaluated through 2 criteria :

- **the initial stability** when upright, for which we will cconsider the metacentric height GM, here computed with a 1° heel angle, so called « GM1° »
- **the righting capacity** when the canoe is impacted by a transversal moment, typically due to a stiff beam wave, for which we will consider the area below the righting moment curve. The righting arm GZ and/or the righting moment RM are use for that study.

Within Gene-Hull, the subroutine in **6.2 Computation, by input of Heel angle, and iteration on Height up to displacement equality** can give :

- for Heel = 0 and interation on Height >>> the Draft, Lwl, Bwl, wetted surface Sw
- for Heel = 1 and interation on Height >>> GM1°
- for any Heel providing that the minimum free board is still positive >>> GZ, RM, FB mini (minimum free-board)

Examples with C2 and a load of 170 kg :

For Heel = 0 , and iteration on Height up to the displacement equality >> Lwl, Bwl, Draft, Sw

6.2 Computation : by input of Heel, and iteration on Height up to displacement equality

Data to enter (yellow cases)		Results					
Heel (°)	**0,00**	**From the Hull :**		**From the Mass :**		Relevant only when heel = 0°	
Height (cm)	**-0,6340**	**> Disp. (m3)**	**0,19524**	**/ Disp. (m3)**	**0,19524**	**Lwl (m)**	**5,149**
		Xc (m)	2,448	Ym (m)	0,00	**Bwl (m)**	**0,793**
		Yc (m)	0,000	**> GZ (cm)**	**0,00**	**Draft (m)**	**0,108**
		Zc (m)	-0,043	> RM (N.m)	0,00	Relevant only when heel = 1°	
		> Sw (m2)	**2,913**	**FB mini (cm)**	**23,4**	**> GM1° (cm)**	**#DIV/0 !**

For Heel = 1 , and a small adaptation on the Height >> GM1°

6.2 Computation : by input of Heel, and iteration on Height up to displacement equality

Data to enter (yellow cases)		Results					
Heel (°)	**1,00**	**From the Hull :**		**From the Mass :**		Relevant only when heel = 0°	
Height (cm)	**-0,6310**	**> Disp. (m3)**	**0,19524**	**/ Disp. (m3)**	**0,19524**	**Lwl (m)**	**5,149**
		Xc (m)	2,448	Ym (m)	-0,01	**Bwl (m)**	**0,793**
		Yc (m)	-0,008	**> GZ (cm)**	**0,21**	**Draft (m)**	**0,108**
		Zc (m)	-0,043	> RM (N.m)	3,96	Relevant only when heel = 1°	
		> Sw (m2)	**2,914**	**FB mini (cm)**	**22,6**	**> GM1° (cm)**	**11,86**

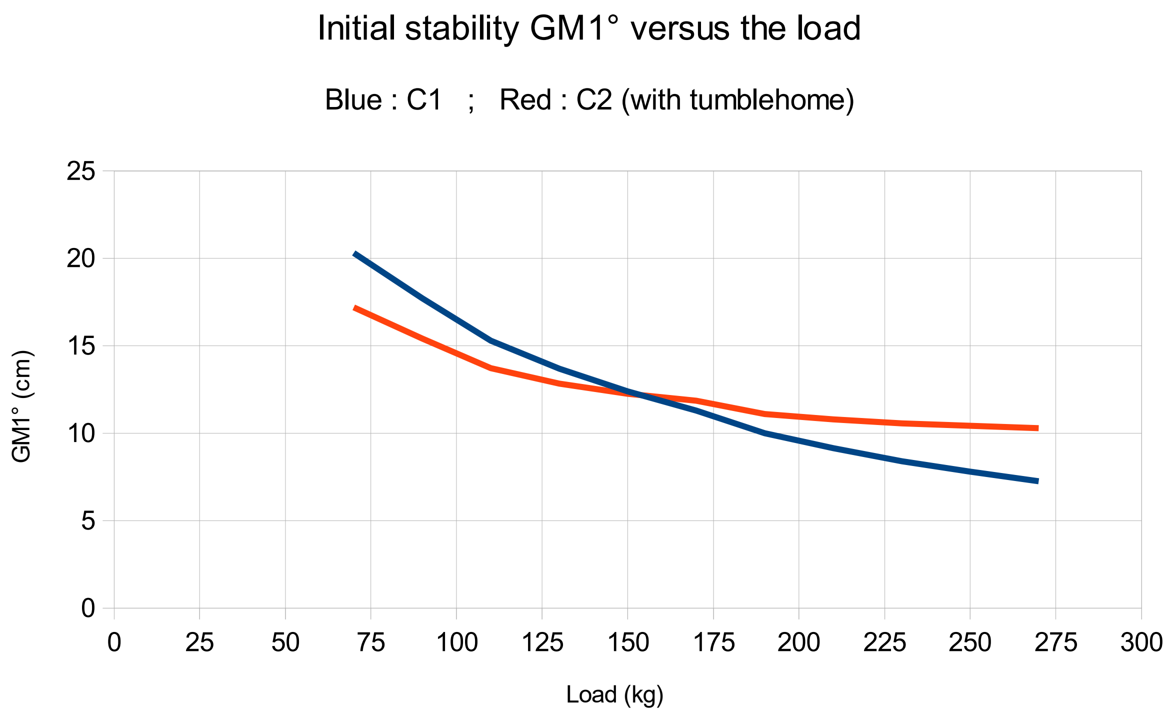
For Heel > 1 (here example with 15°), and iteration on the Height >> GZ, RM, FB mini

6.2 Computation : by input of Heel, and iteration on Height up to displacement equality

Data to enter (yellow cases)		Results					
Heel (°)	**15,00**	**From the Hull :**		**From the Mass :**		Relevant only when heel = 0°	
Height (cm)	**0,5305**	**> Disp. (m3)**	**0,19524**	**/ Disp. (m3)**	**0,19524**	**Lwl (m)**	**5,121**
		Xc (m)	2,451	Ym (m)	-0,08	**Bwl (m)**	**0,762**
		Yc (m)	-0,106	**> GZ (cm)**	**2,21**	**Draft (m)**	**0,096**
		Zc (m)	-0,046	> RM (N.m)	42,31	Relevant only when heel = 1°	
		> Sw (m2)	**2,805**	**FB mini (cm)**	**12,1**	**> GM1° (cm)**	**8,54**

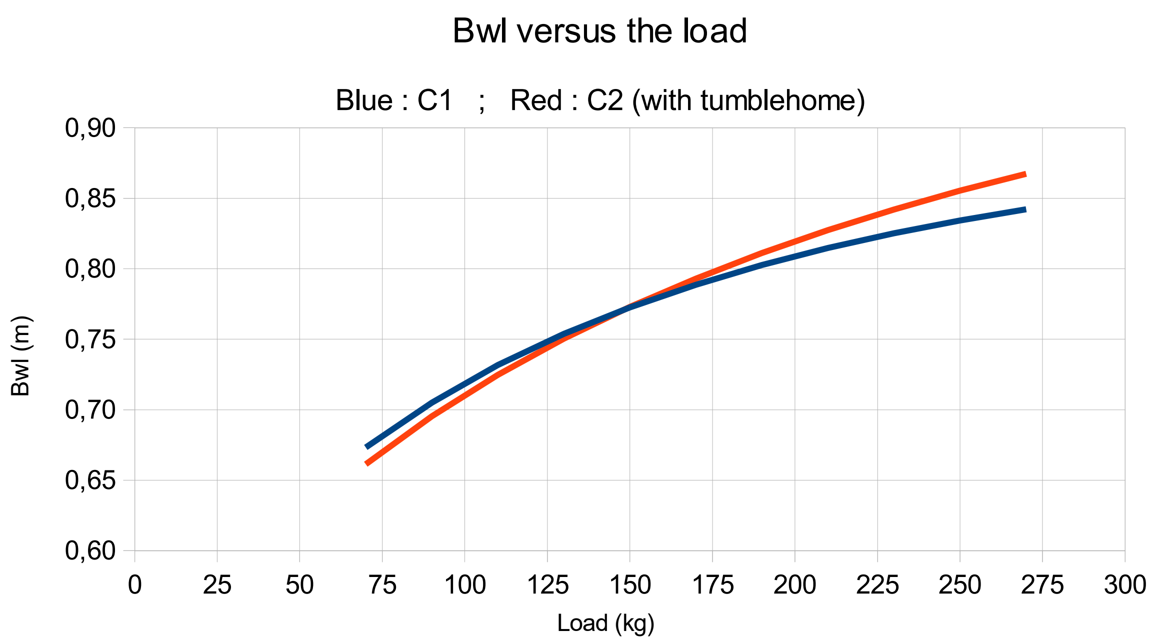
The use of this subroutine allows the construction step by step of the following curves concerning GM1° (the variable is then load input) and of the GZ and RM curves (the variable is then the heel angle for a given load). It is not automatised unfortunately (*as it seems (to me) impossible to do that in the frame of a spreadsheet*), but with a bit of training it is not a long task to do.

2.1 The initial stability



Comment :

- For a light loading, C1 shows a better initial stability
- For a heavy loading, it is C2 which hows a better initial stability
- The 2 curves crosses for a load of ~ 154 kg which, with the addition of the canoe proper weight, corresponds to the same displacement (178,7 kg), the same draft (0,102 m , 4'') and the same Bwl (0,777 m) for which the two hulls were initially designed.
- This GM trend is closely similar with the waterline beam Bwl evolution with the loading : C2 has a lower Bwl for light load and a greater Bwl for heavy loading.



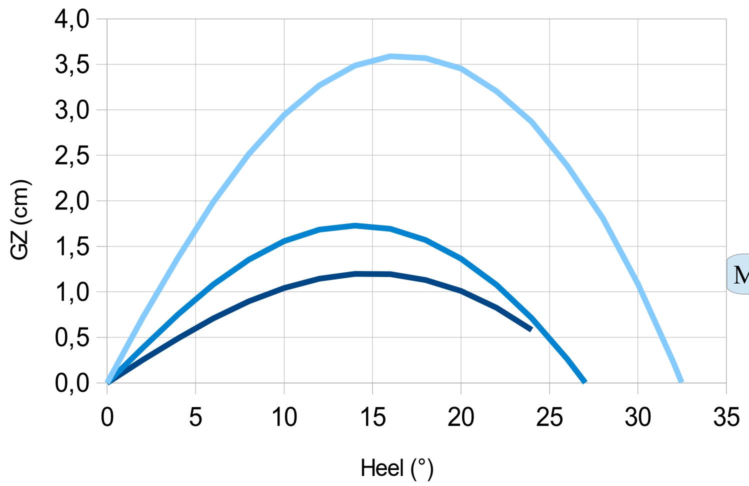
2.2 The righting capacity

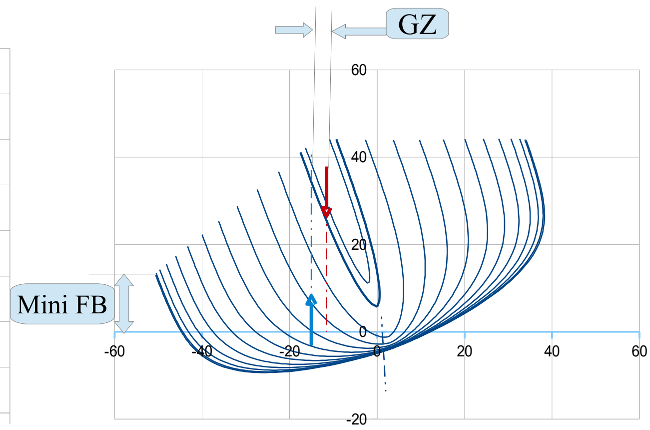
For this study, we consider the righting moment RM curves for 3 loading (70kg, 170 kg, 270 kg).

At first, let's show the **influence of the loading for the C1 version :**

C1 - Righting arm GZ versus the heel

Light blue : load 70 kg ; Blue : load 170 kg ; navy blue : load 270 kg

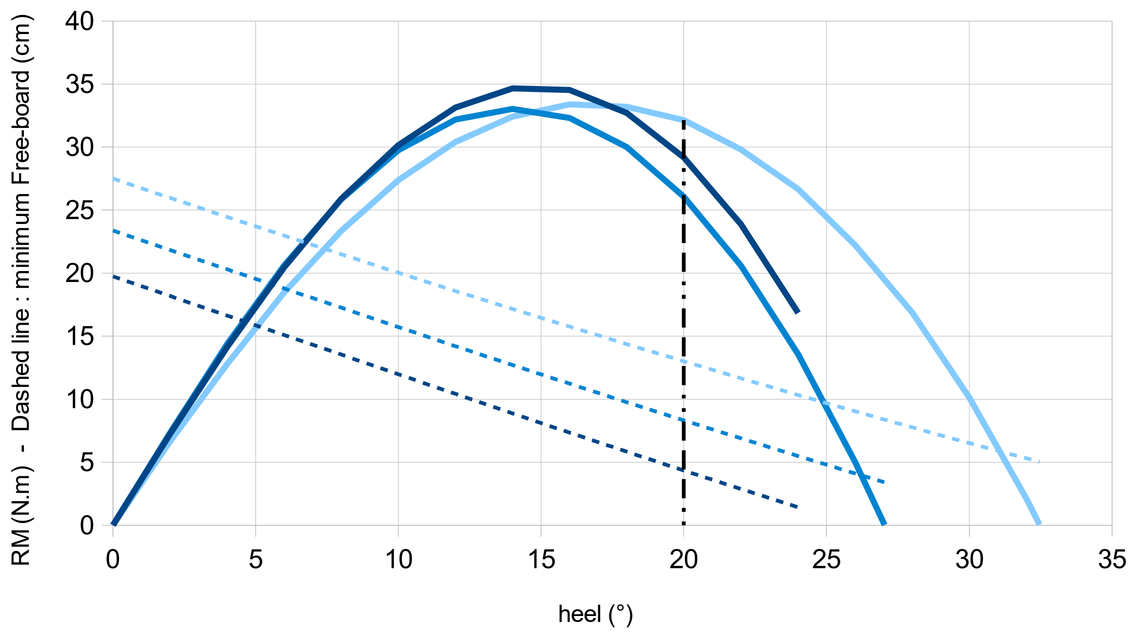




>>> which lead, for the righting moment **RM = GZ * Displacement ,** to :

C1 - Righting moment RM versus the heel

Light blue : load 70 kg ; Blue : load 170 kg ; navy blue : load 270 kg
(dashed lines : minimum free-board)



Comments :

- In the top view, the righting arm GZ for a light load is greater than for an heavy one, a logical result in line with the better initial stability see before (and here represented by the beginning slope)
- But when considering, in the bottom view, the righting moment RM, i.e. Gz * Displacement, the 3 curves becomes very similar.
- Also in this view is shown the evolution of the minimum free board, because of course the RM curve has sense only if the free board is still positive by a margin, i.e. without risk of flooding by the gunwale.
- So, the question is what could be the relevant figure to quantify the righting capacity to restore from a transversal moment impact, which can be used for the comparison of the various loadings and/or the various designs : from the bottom view, I propose to consider the area under the RM curve up to 20° heel angle, as beyond 20° the angle is becoming inconfortable and the remaining free-board is becoming low, just 5 cm – 2'' when the loading is 270 kg >>>

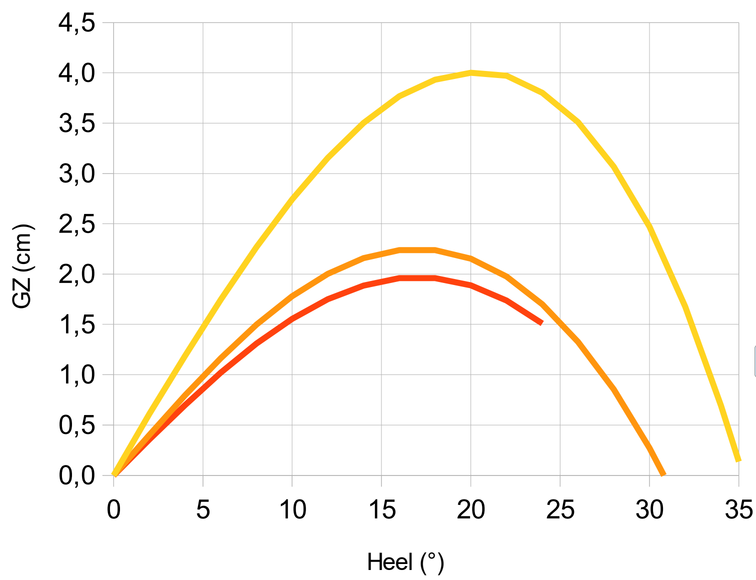
  with load 70 kg >> RM*Heel20° area = 468,2 N.m.deg
  with load 170 kg >> RM*Heel20° area = 477,0 N.m.deg
  with load 270 kg >> RM*Heel20° area= 495,0 N.m.deg

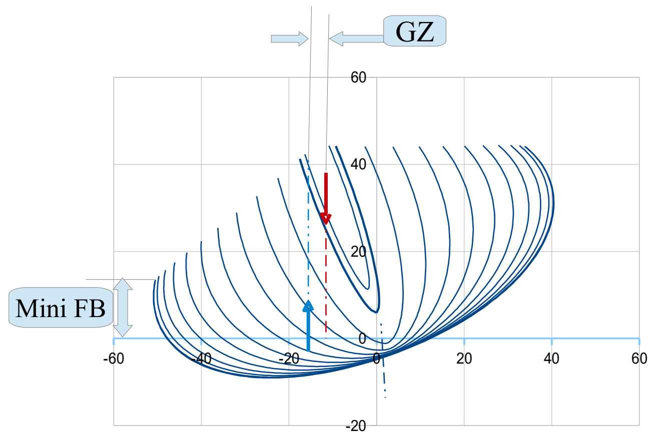
Let's consider 477 N .m.deg the reference RM*Heel20° area for the C1 straight version with its average load 170 kg : when load is varying from 70 kg to 270 kg (at same Zg) the RM*Heel20° is quasi constant, varying from just 0,98 to 1,04.

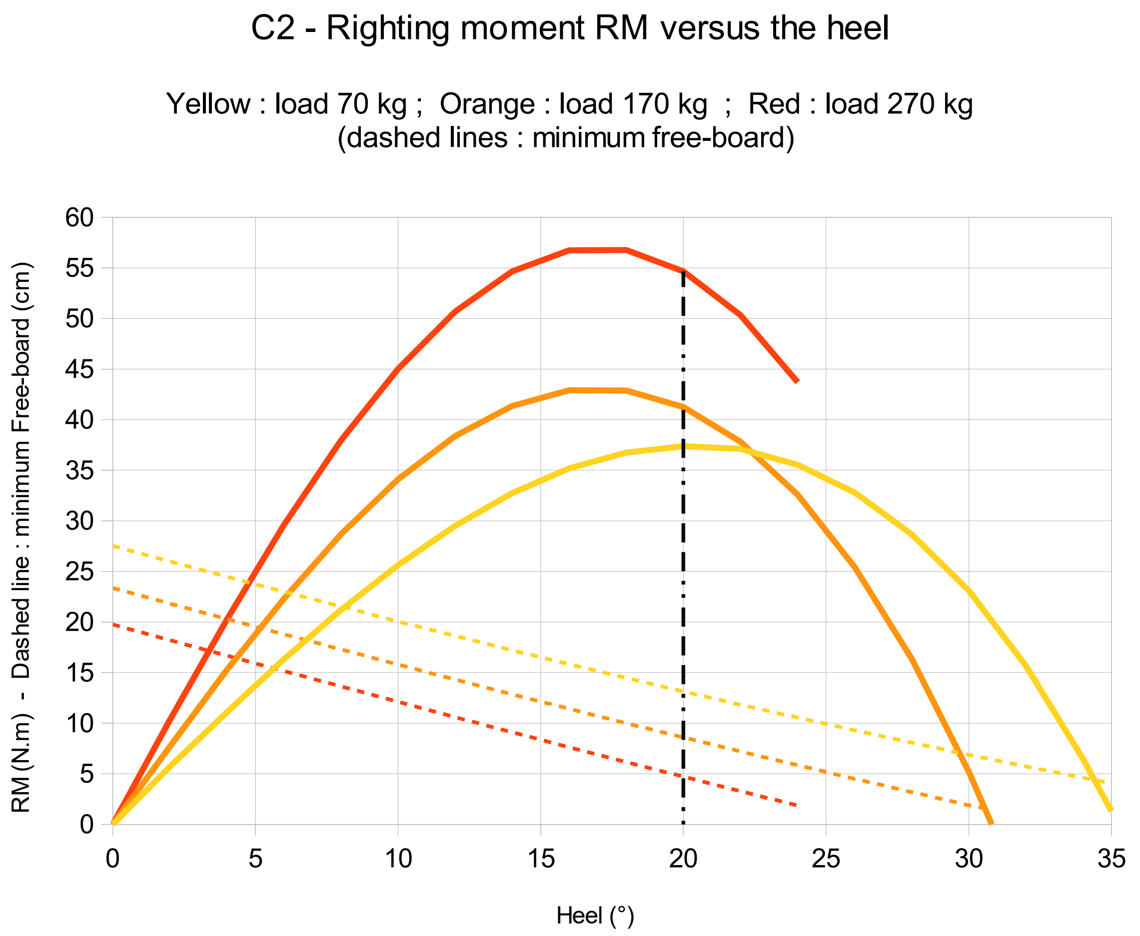
Influence of the loading for the C2 version :

C2 - Righting arm GZ versus the heel

Yellow : load 70 kg ; Orange : load 170 kg ; Red : load 270 kg





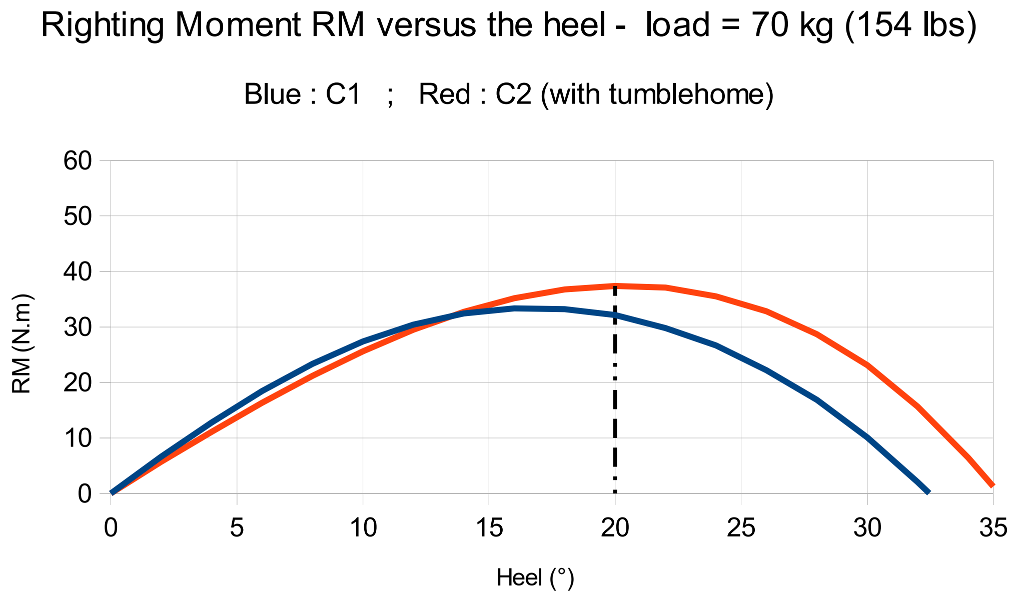


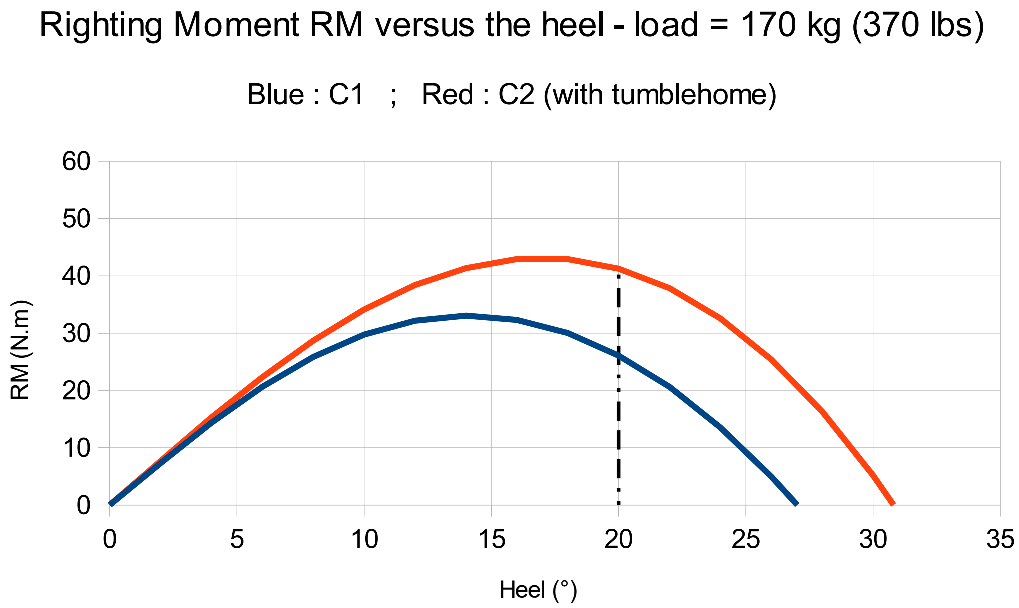
Comments :

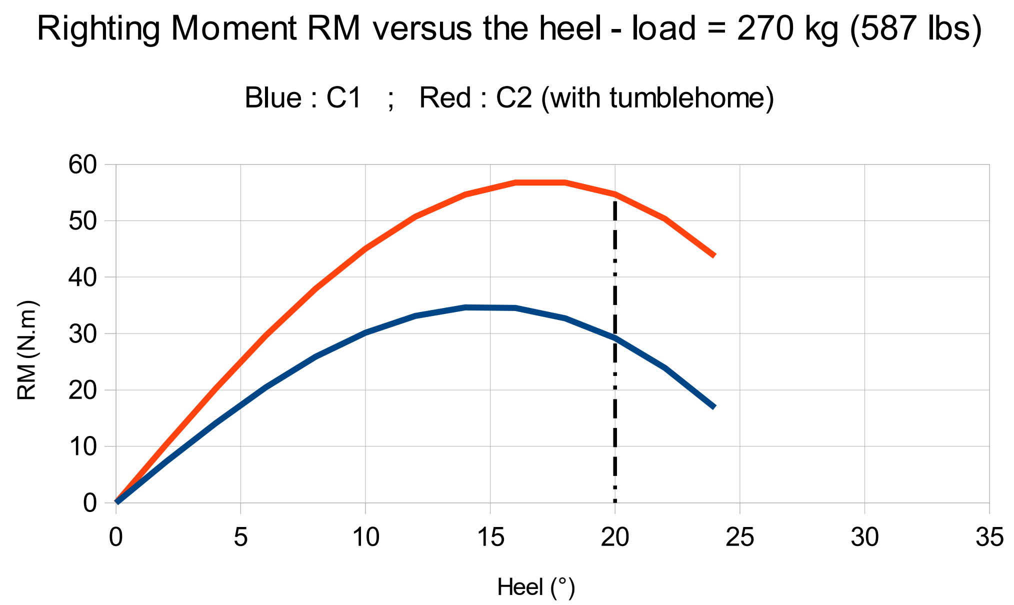
- As for C1, the righting arm GZ for a light load is greater than for an heavy one,
- But at contrary, when considering in the bottom view the righting moment RM, i.e. Gz * Displacement, the 3 curves show a better righting capicity with increasing the loading, an advantage of this design with tumblehome.
- For the RM curves up to 20° heel angle, the remaining free-board is also about 5 cm – 2'' in the worst case when the loading is 270 kg. So we can also consider the RM*Heel20° area as the relevant quantity :

  with load 70 kg >> RM*Heel20° area = 465,6 N.m.deg >> 0,99 / C1
  with load 170 kg >> RM*Heel20° area = 588,3 N.m.deg >> 1,23 / C1
  with load 270 kg >> RM*Heel20° area= 778,6 N.m.deg >> 1,57 / C1

The better righting capacity of C2 / C1 is significant, also show by a direct C1/C2 comparison of their RM curves at same loading :


Righting Moment RM versus the heel - load = 70 kg (154 lbs)
Blue : C1 ; Red : C2 (with tumblehome)
RM (N.m)
Heel (°)
0
5
10
15
20
25
30
35
40
50
60


Righting Moment RM versus the heel - load = 170 kg (370 lbs)
Blue : C1 ; Red : C2 (with tumblehome)
RM (N.m)
Heel (°)
0
5
10
15
20
25
30
35
40
50
60


Righting Moment RM versus the heel - load = 270 kg (587 lbs)
Blue : C1 ; Red : C2 (with tumblehome)
RM (N.m)
Heel (°)
0
5
10
15
20
25
30
35
40
50
60

Conclusion on the stability issue :

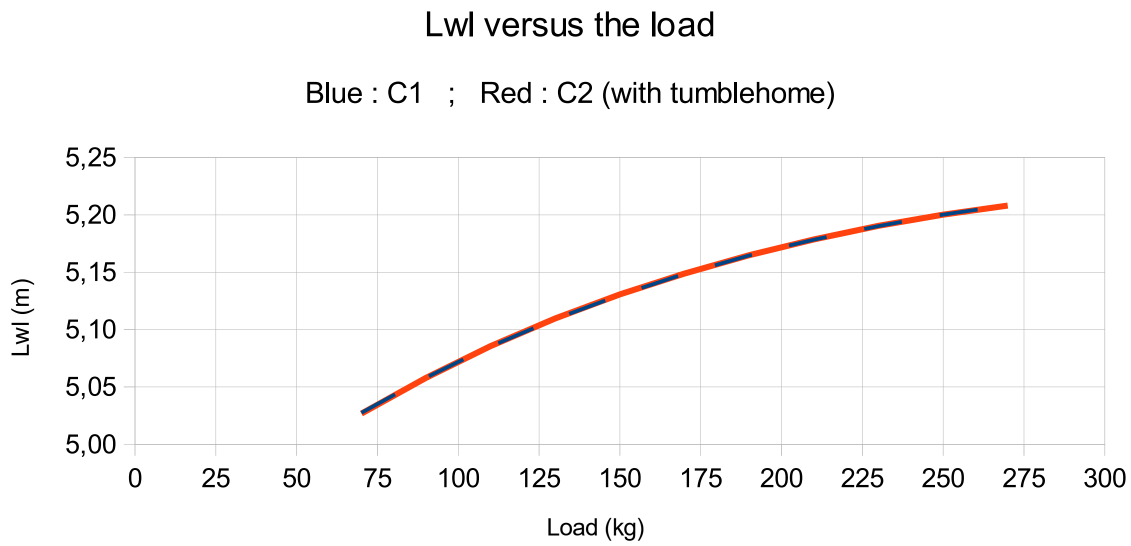
	C1	**C2 (with tumblehome)**
Initial stability >> GM1° (cm)		
With load 70 kg (154 lbs)	20,3	17,2 (> - 15%)
With load 170 kg (370 lbs)	11,3	11,9 (> + 5%)
With load 270 kg (587 lbs)	7,3	10,3 (> + 41%)
Righting capacity in dynamic >> RM*Heel 20° area (N.m.deg)		
With load 70 kg (154 lbs)	468,2	465,6 (> - 0,5%)
With load 170 kg (370 lbs)	477,0	588,3 (> + 23%)
With load 270 kg (587 lbs)	495,0	778,6 (> + 59%)

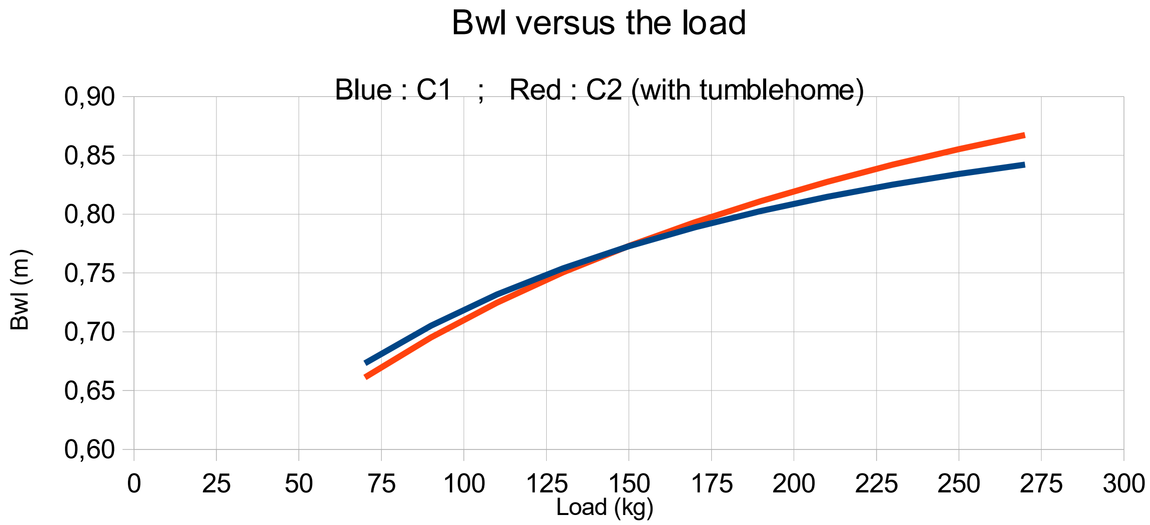
This synthesis shows the advantage of the C2 tumblehome shape regarding the stability concern, except the initial stability with a light loading for which the C1 version is a bi better.

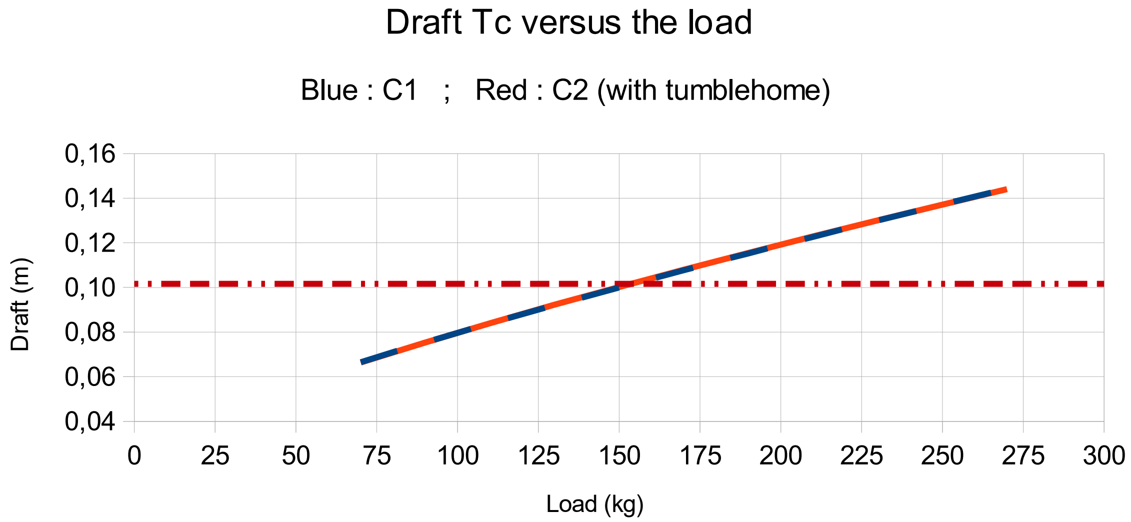
To note that it is not here mentioned of the maximum righting moment RM itself as it is a steady feature relevant in the case of a sailing boat to compensate a steady heeling arm, less relevant for a canoe which impulsion of transversal moment.

3. The performance issue : estimation of the drag and of the speed potential

3.1 Lwl, Bwl and draft evolution with the loading





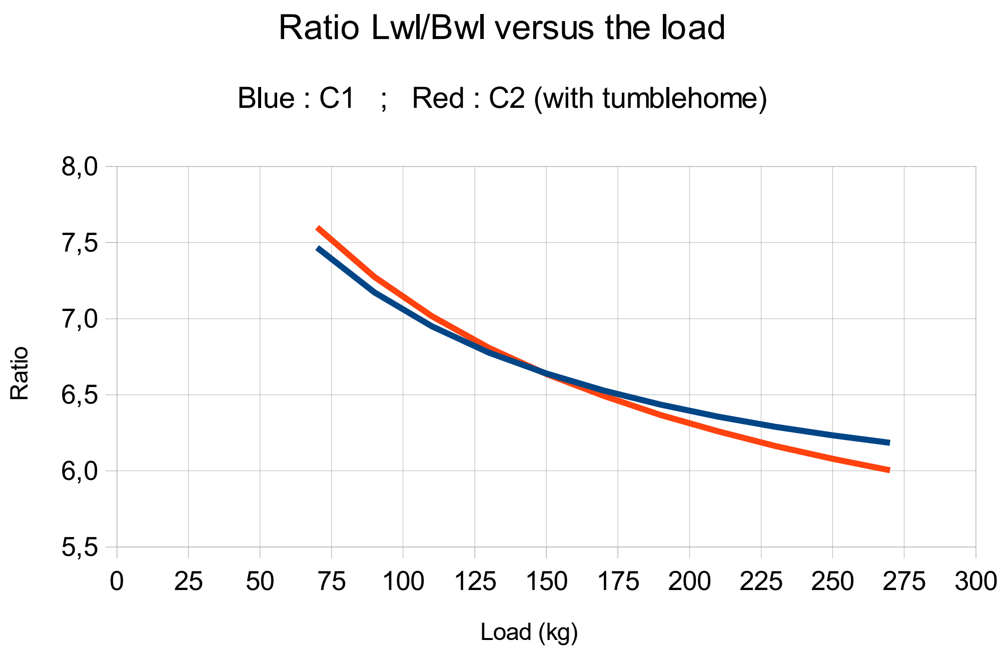


Comments :

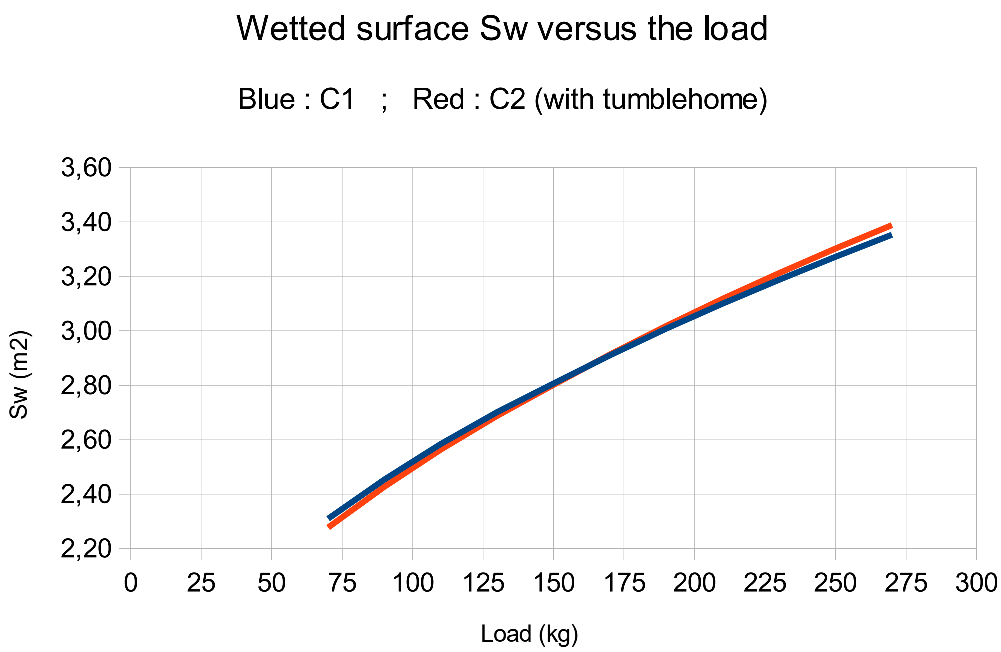
Draft and Lwl evolution are strictly identical, Bwl evolution is different : C2 version shows a narrower beam when light loaded (66,1 cm / 67,3 cm, so -1,8 % with load 70 kg) and larger beam when heavy loaded (86,7 cm / 84,2 cm, so +3 % with load 270 kg). This should influence a bit the wave drag, at the max in proportion of the squared Bwl according to Michell theory.

>> with 70 kg of load : C2 can have 0,982^2 >> -3,6 % the wave drag of C1
>> with 270 kg of load : C2 can have 1,030^2 >> +6,0 % the wave drag of C1

Another way to appreciate this Bwl influence is to show the ratio LwL/Bwl for the 2 versions :



3.2 Wetted surface Sw evolution with the loading



Comments :

The differenciation between the two versions is very low concerning the Sw :

>> with 70 kg of load : C2 Sw = 2,277 m2 / C1 Sw = 2,309 m2 >> -1,4 % Sw of C1
>> with 270 kg of load : C2 Sw = 3,388 m2 / C1 Sw = 3,353 m2 >> +1,0 % Sw of C1

3.3 Tentative estimation in terms of drag and speed

This estimation is done within Gene-Hull by the VPP sheet, based on an estimation of the drag components as detailed in the User Guide, in particular for the residuary component a tentative adaptation of the Delft series formulation as reported by Larsson & Eliasson in their book « Principles of Yacht Design - 2nd edition 2000 », although the ratio Lwl/Bwl of canoes design (~ 6 to 7,5 as shown here above) is usually outside the range of validity of the formulation (2,76 – 5,0) reflecting the model test results. To take that into account, I have adopted a reduction factor for the residuary drag, evolving from 1 (when Lwl/Bwl = 5) to 0,5 (when Lwl/Bwl ~ 8) to make a transition towards a slender body.

For Gene-Hull user : the VPP computation is in automatical connection with the (input and ouput) data coming from the Gene-Hull sheet. Just 3 additionnal data are necessary to input in this sheet (in the yellow cases) :

Data from Gene-Hull (except the data to input in the yellow cases)

Sa hull	**S person(s)**	**Cd aero**	Dép. (kg)	Lwl (m)	v (m2/s)	Lwl/Bwl	Bwl/Tc	Lwl/D^1/3	Cp	LCB
0,37	**0,74**	**0,5**	94,81	5,027	1,00E-006	7,47	10,12	11,03	0,621	-2,39
	Water mass / vol. (kg/m3)		1000	Vol hull (m3)	Sw Hull 0°	Bwl (m)	Tc (m)			
				0,09481	2,309	0,673	0,0665			

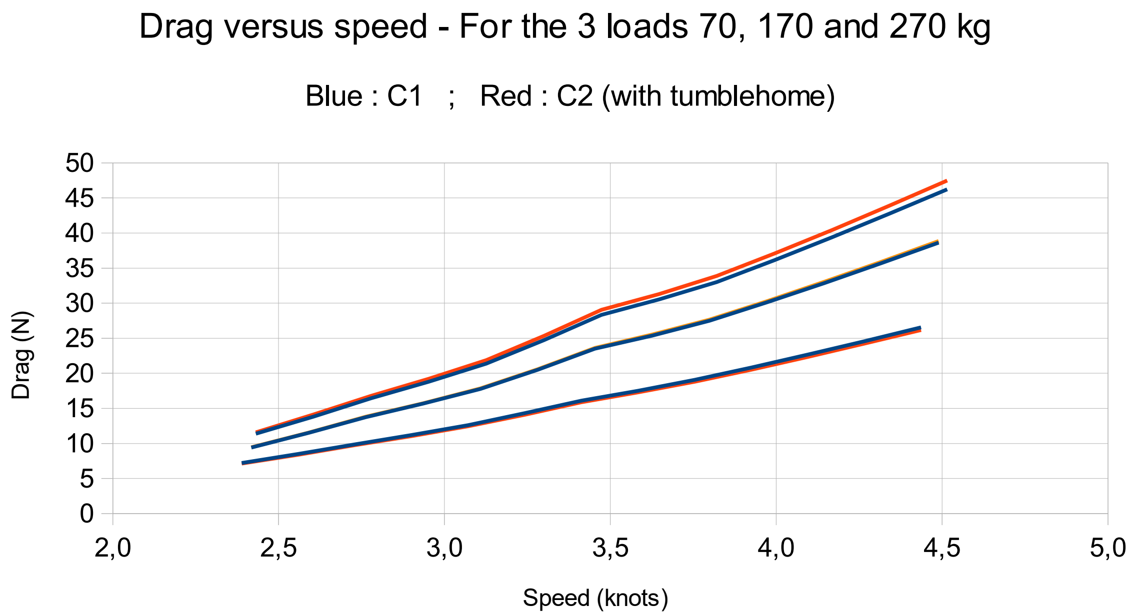
At constant power on flat sea with Head wind :	**Power (W)**	**70,0**

** **S person(s)** is the cross-section of the paddler(s) body, here estimated by 0,37 m2 * 2 paddlers = 0,74 m2

** **Cd aero** is the aero drag estimated coefficient, applying to both the canoe cross-section (Sa hull) and the 2 paddlers body (S Person(s))

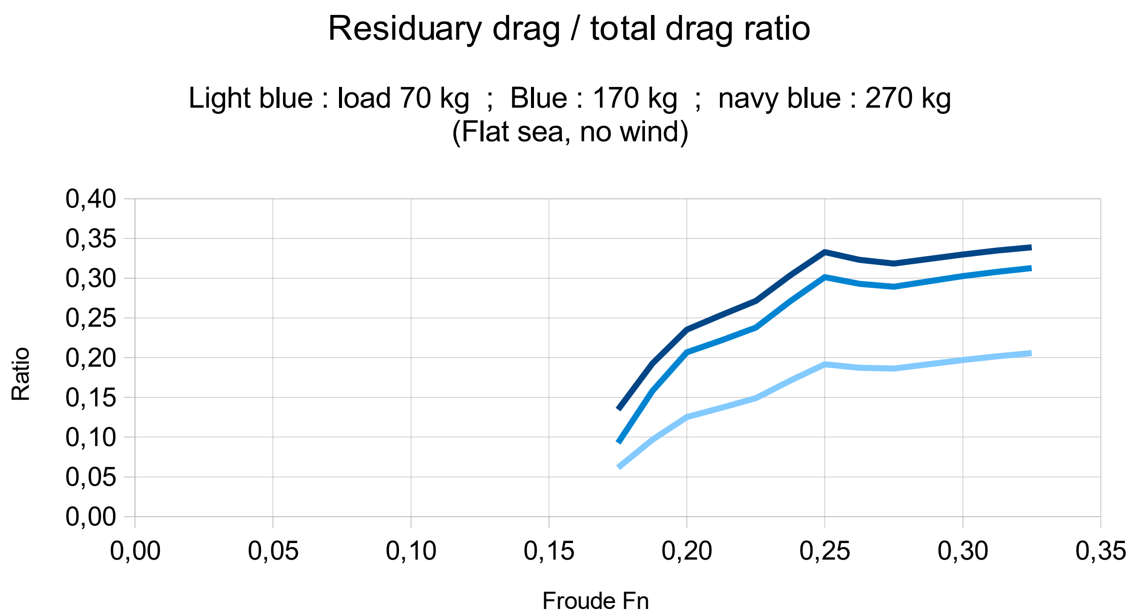
** **Power (W) :** here you can put an estimated net power of propulsion to see which speed you can reach with, with head wind from 0 to 24 knots. This info complete the drag one and is more explicit to compare two design versions. ~ 70 W net is an order of magnitude for 2 paddlers into a few hours effort (~ 40 W for 2 kids, ~ 100 W for two trained heavy paddlers)

Total drag with the 3 loads for the 2 versions C1 and C2, as computed by the VPP subroutine :



Comments : The difference between the two versions is not significant for light and medium loadings, and just a bit more drag for C2 with heavy loading, ~2% to 3% more / C1.

Another interesting output is to show the relative amount of residuary drag in the total, for the 3 loadings, in adimensional i.e. in function of Froude Fn . The results is the same for the 2 versions C1 and C2 :



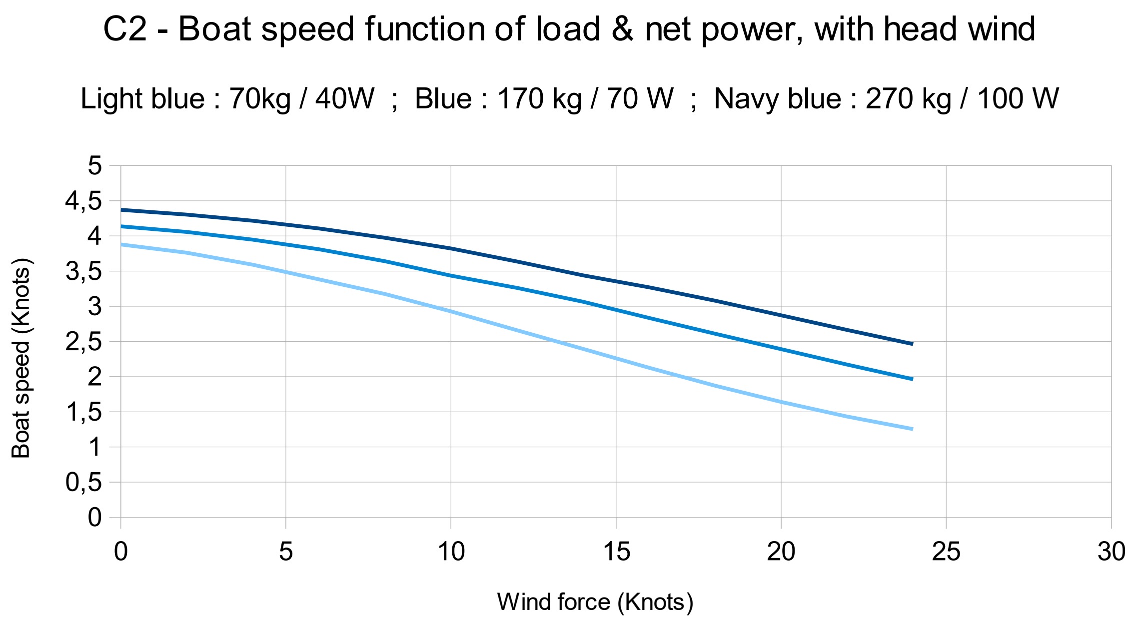
Comment : For a light loading, the residuary drag counts for about 20 % of the total drag in the design zone ; For medium to heavy loading, the residuary drag counts for 30% to 33%.

Finally a speed estimation can be done with the VPP when introducing a propulsion net power,

Examples :

- 70 kg / 2 kids >> 40 W
- 170 kg / 2 adults >> 70 W
- 270 kg / 2 trained heavy adults >> 100 W

Examples done with C2 (results with C1 being quasi identical) :



3.4 Conclusion on the performance estimation and C1/C2 comparison

For the medium loading around 170 kg, performance are equivalent. Only for light load (70 kg) or for heavy one (270 kg) , performance are very slightly different.

	Load 70 kg		**Load 270 kg**	
	C1	C2	C1	C2
Lwl (m)	5,027	5,027	5,208	5,208
Bwl (cm)	67,3	66,1	84,2	86,7
Lwl/Bwl	7,47	7,60	6,18	6,00
Sw (m2)	2,309	2,277	3,353	3,388
Drag estimation (N) at Froude Fn = 0,325	**26,55**	**26,17**	**46,24**	**47,49**
	With propulsion net power 40 W		**With propulsion net power 100 W**	
Speed estimation (Knots) (flat sea, no wind)	3,86	3,88	4,41	4,30