SA-VPP Catamaran 1.0_User Guide

SA-VPP Catamaran (Velocity Prediction Program) makes possible the prediction of the catamaran speed and of the heel angle for 3 typical sailing conditions by wind 4 to 20 Knots :

- Upwind on calm water
- Beam reaching, twa 90°
- Downwind with spi, twa 135°

The main goal is to provide a helpful tool one can integrate in the design loop to optimise a project at its early stage with regard the performance objectives, able to show and to quantify in terms of boat speed the influence of such or such parameter and so to guide the project towards an optimum. The input consists of a relatively short list of data representative of both hulls of the catamaran with a differentiation between the leeward and the windward one, the appendages (daggerboard, rudder), the displacement, the sailplan, the righting moment, the wetted surface. The ouput are the speed curves with wind force for these 3 sailing conditions, as also the heel angles, the displacement repartition between the two hulls and the drags.

It is a free and open source speadsheet application, developed on a support itself free and widespread (Open Office Calc 4.0.1) : to open and use an ods file, you have to download Open Office or Libre office according to : http://www.openthefile.net/extension/ods

This application can be used stand alone, in complement to any other software used for a project development and providing the necessary data. For the User of « Gene-Hull Catamaran 3.0 » application, the set of input data for « SA-VPP » is generated partly automatically and partly by the User following a process descibe in the User guide of this application : once the ad hoc table of data is fulfilled, you have then just to copy/special paste these data. In the present User Guide, you will find all information necessary to prepare this set of data, whatever their upstream source. For any questions or improvement requests, you can contact me.

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Summary presentation

The spreasheet application includes 2 sheets :

- SA-VPP
- Data storage

SA-VPP : includes an User space (input & outputs) followed by an Administrator space (from line 131) where all the computations are carried out. The User space includes 2 sections :

SA-VPP input :

1. Input data

SA-VPP output :

2. Output data
   - 2.1 Upwind on calm water
   - 2.2 Beam reaching, twa 90°
   - 2.3 Downwind with spi, twa 135°
   - 2.4 Figures about Boat speed, Heel angle, %Displacement supported by the windward hull, Flat optimum, Righting Moment RM, Drag,
   - 2.5 Other figures about parameters of each hull of the heeled catamaran

Data storage : is the storage space of the input data.

SA-VPP sheet / 1. Input data

The input data can be fulfilled step by step from any catamaran project. The present User guide first address this process.

If you use « Gene-Hull Catamaran 3.0» for your early stage project, the input data are prepared partly automatically and partly by the User, and once the dedicated table of data is fulfilled, then you have just to copy/special paste it towards the SA-VPP spreadsheet. This approach is also adressed in the present User Guide.

The table of data to enter are in lines 10 to 22, columns A to K, cells B12 to B68.
Example with catamaran C1 values (the reference boat of Gene-Hull Catamaran, also stored in the sheet « Data storage ») :

For SA-VPP	Heel (°)	Lwl (m)	Bwl (m)	Tc (m)	Cp	LCB (%Lwl)	Sf (m2)	Sw tot (m2)	Disp. (m3)	RM (kN.m)
Lee Hull	0,0	15,32	1,62	0,79	0,563	46,4	17,82	29,67	8,079	17,658
Wind Hull	0,0	15,32	1,62	0,79	0,563	46,4	17,82	29,67	8,079	
Lee Hull	4,0	16,00	1,77	0,98	0,583	46,9	20,50	36,26	11,758	219,024
Wind Hull	4,0	13,13	1,42	0,56	0,576	44,1	13,73	21,60	4,399	
Lee Hull	8,0	16,00	1,89	1,12	0,609	47,0	22,08	39,58	14,760	372,834
Wind Hull	8,0	9,90	1,12	0,29	0,602	44,5	8,34	13,01	1,397	

Each daggerboard				Each rudder			Hull beam	Hulls axis space		
Vol. (m3)	Sw (m2)	Chord (m)	Draft (m)	Vol. (m3)	Sw (m2)	Chord (m)	Boa (m)	Space (m)		
0,06612	2,37	0,70	2,80	0,01904	1,15	0,40	1,97	6,10		

From the Sailplan sheet :							Adjustments		
SA (m2)	ZCE (m)	Zdeck (m)	Zmast (m)	Main (m2)	Spi (m2)	ZCE spi (m)	Reefing	Flat mini	Windward daggerboard
147,15	9,11	1,15	22,72	81,50	229,78	10,54	1,00	0,5	1,0

The 2 hulls bodies parameters when upright and heeled

For SA-VPP	Heel (°)	Lwl (m)	Bwl (m)	Tc (m)	Cp	LCB (%Lwl)	Sf (m2)	Sw tot (m2)	Disp. (m3)	RM (kN.m)
Lee Hull	0,0	15,32	1,62	0,79	0,563	46,4	17,82	29,67	8,079	17,658
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Lee Hull	8,0	16,00	1,89	1,12	0,609	47,0	22,08	39,58	14,760	372,834
Wind Hull	8,0	9,90	1,12	0,29	0,602	44,5	8,34	13,01	1,397	

Heel angles :

3 heel angles are involved to capture the necessary data from which the programme will set interpolated formulations for each hull parameter versus the heel. Besides heel = 0° which is mandatory, we recommend to choose an angle which corresponds to a windward hull quasi emerged (here above : 8° which corresponds to 0,09 D for the windward hull) and an intermedaite angle which could be (but not necessary) half the previous one (here above : 4°). The « static » equilibrium for these 3 heel angles can give you (with your software or with Gene-Hull) the following data :

For each hull :

Lwl (m) : lenght of waterline

Bwl (m) : beam of waterline

Tc (m) : maximum draft of the hull body

Cp : prismatic coefficient of the hull body

LCB (%) : longitudinal location of the center of buoyancy of the hull body, counted from the rear point of the waterline and in % of the Lwl

Sf (m2) : waterline area

Sw tot (m2) : wetted area, inc. the daggerboard and the rudder

Disp. (m3) : displacement, inc. the daggerboard and the rudder

For the catamaran as a whole :

RM (kN.m) : righting moment

Daggerboard

Each daggerboard			
Vol. (m3)	Sw (m2)	Chord (m)	Draft (m)
0,06612	2,37	0,70	2,80

Vol.(m3) : volume of each daggeboard

Sw (m3) : wetted area of each daggerboard

Chord (m) : root chord of the daggerboard profile (this data is used to compute the Reynolds)

Draft (m) : draft of the catamaran when upright with the daggerboards deployed

Rudder

Each rudder		
Vol. (m3)	Sw (m2)	Chord (m)
0,01904	1,15	0,40

Vol. (m3) : volume of each rudder

Sw (m2) : wetted area of each rudder

Chord (m) : root chord of the rudder (this data being used to compute the Reynolds)

Hull beam and hull axis space

Hull beam	Hulls axis space
Boa (m)	Space (m)
1,97	6,10

Boa (m) : Beam overall of each hull

Space (m) : Space between the 2 hulls axis

Sailplan

From the Sailplan sheet :						
SA (m2)	ZCE (m)	Zdeck (m)	Zmast (m)	Main (m2)	Spi (m2)	ZCE spi (m)
147,15	9,11	1,15	22,72	81,50	229,78	10,54

SA (m2) : Sails area, exactly Mainsail + Fore triangle

ZCE (m) : height of the center of effort of SA / waterplane

Zdeck (m) : height of the deck at foot step / waterplane

Zmast (m) : height of the mast (exactly the end point of the mainsail)/ waterplane

Main (m2) : Mainsail area

Spi (m2) : Spinnaker area

ZCE spi (m2) : height of the center of effort of Mainsail+Spi

Adjustments

Adjustments		
Reefing	Flat mini	Windward daggerboard
1,00	0,5	1,0

Reefing : coefficient.

Reefing = 1 >>> above sails area and ZCE are taken unchanged

Reefing < 1, for example 0,8 :

>>> sails area are reduced by (0,8) ^2 = 0,64

>>> (ZCE - Zdeck) is lower by 0,8

Flat mini : Flat is a coefficient, between 1 and Flat mini, which can numerically « flatten » the camber of the sails through the reduction of the Lift coefficient. Flat mini is usually 0,5 but you can introduce a higher value if you consider that your sails (when used or not well cut) cannot be flatten perfectly.

Windward daggerboard : = 1,0 means the daggerboard fully deployed
= 0,0 means the daggerboard is retracted
(an intermediate value is possible)

For the User of Gene-Hull Catamaran : the preparation of the table of input data is helped and partly automatic, it is decribed in the User guide of this application.

SA-VPP sheet / 2. Ouput data

From line 25 : SA-VPP gives the speed predictions for 3 cases supposed to be representative of the sailboat typical sailing, in order to help optimize the sailboat design through further iterations :

2.1 Upwind on calm water
2.2 Beam reaching, twa 90°
2.3 Downwind with spi, twa 135°
2.4 Figures about Boat speed, Heel angle, %Displacement supported by the windward hull, Flat optimum, Righting Moment RM, Drag,

2.5 Other figures about parameters of each hull of the heeled catamaran

To note that, when the windward hull is fully emerged, i.e. its % of Displacement is 0, the output results are not showed.

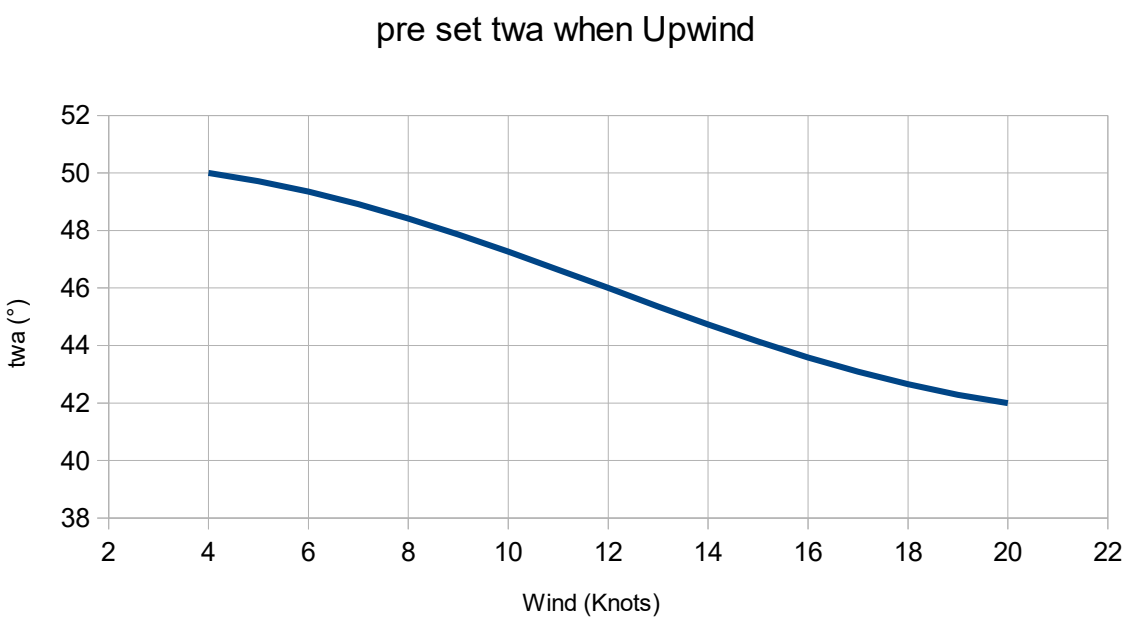
2.1 Upwind on calm water

Output data are in lines 27 to 47 , columns A to BE , including :

Wind		Ship heel		Ship speed			
Vw10 (Knots)	**twa** (°)	**Phi** (°)	**% of Disp.** on Windward hull	**Vb** (Knots)	**VMG** (Knots)	Vb (m/s)	½ Rho Vb^2

Vw10 : wind force at 10 m above the water, from 4 to 20 Knots, step 1 knot
twa : pre set true wind angle (no iteration on this parameter of which influence is second order with regard to the Flat one for the VMG optimisation)

Vw10 (Knots)	**twa** (°)
4	50,00
5	49,71
6	49,35
7	48,91
8	48,41
9	47,86
10	47,27
11	46,64
12	46,00
13	45,36
14	44,73
15	44,14
16	43,59
17	43,09
18	42,65
19	42,29
20	42,00



Phi : Ship heel angle
% of Disp. : the % of displacement supported by the windward hull (= 50 when the boat is upright, =0 when the hull is fully emerged)
Vb : boat ship
VMG : Velocity made good
Pdyn = ½ Rho Vb^2 : Dynamic pressure (used in various computations)

		Apparent wind	
HM – RM (% RM max)	**Thrust–Drag** (% Disp.)	**Ba** (°)	**Va** (Knots)

HM-RM = Heeling Moment – Righting Moment

Thrust – Drag : Thrust force (provided by the sails) – Drag force (hull and its appendages resistance)
Ba : apparent wind angle (also called « awa »)
Va : apparent wind force

Sails								
Reefing	Flat	CL	CD	CL/CD	Ft (kN)	Fs (kN)	Mh/Fs (m)	HM (kN.m)

Reefing : input coefficient, Reef = 1 >>> above sails area and ZCE are taken unchanged
Reef < 1, for example 0,8 :
>>> sails area are reduced by (0,8) ^2 = 0,64
>>> (ZCE - Zdeck) is lower by 0,8
Flat : coefficient between 1 and Flat mini which can numerically « flatten » the camber of the sails through the reduction of the Lift coefficient : CL = Flat x CLo
CL , CD : Lift, Drag coefficient
Ft, Fs : Thrust and Side forces
Mh/Fs : Heeling arm
HM : Heeling Moment

Tc Lee (m)	Lwl Lee (m)	D Leeward (m3)	Tc Wind (m)	Lwl Wind (m)	D Windward (m3)	RM (kN.m)

For Leeward and for Windward hulls, depending of the heel angle :
Tc : hull body draft
Lwl : length of waterline
D : displacement
For the catamaran as a whole, depending of the heel angle :
RM : righting moment

Hulls-daggerboards-rudders : frictional drag Df					
Sw hull Lee (m2)	Re hull	Cf hull	Sw hull Lee (m2)	Re hull	Cf hull

For Leeward and Windward hulls, depending of the heel angle :
Sw hull : wetted surface of the hull body
Re hull : Reynolds number
Cf hull : Friction coefficient

Re dagger	Cf dagger	Re rudder	Cf rudder	Dwet (kN)

For the daggerboards and the rudders :
Re hull : Reynolds number
Cf : Friction coefficient

For the whole catamaran :
Dwet : Friction drag (leeward + windward hulls + 1 or 2 daggerboards + 2 rudders)

Hull Residuary drag Dr							
Fn Lee	> Dr/mg (%)	K interhull	Dw Lee (kN)	Fn Lee	> Dr/mg (%)	K interhull	Dw Wind (kN)

For Leeward and for Windward hulls, depending of the heel angle :

Fn : Froude number
Dr/Mg : adimensional residuary drag
K interhull : extra drag coefficient due to the wave interaction
Dw : residuary drag

D ind (kN)	Daero (kN)	Dtot (kN)

Dind: induced drag (due to the lateral resistance of the hulls and appendages)
Daero : aerodynamic drag (hulls, rig)
Dtotal : total drag

2.2 Beam reaching, twa 90°

Output data are in lines 53 to 73 , columns A to BD

Same output as above but :

- without VMG (without interest in that case)
- with Flat maintain at 1 (no need to flatten the sails a priori)

2.3 Downwind with spi, twa 135°

Output data are in lines 79 to 99 , columns A to BK

Same output as above + for the Spi itself :

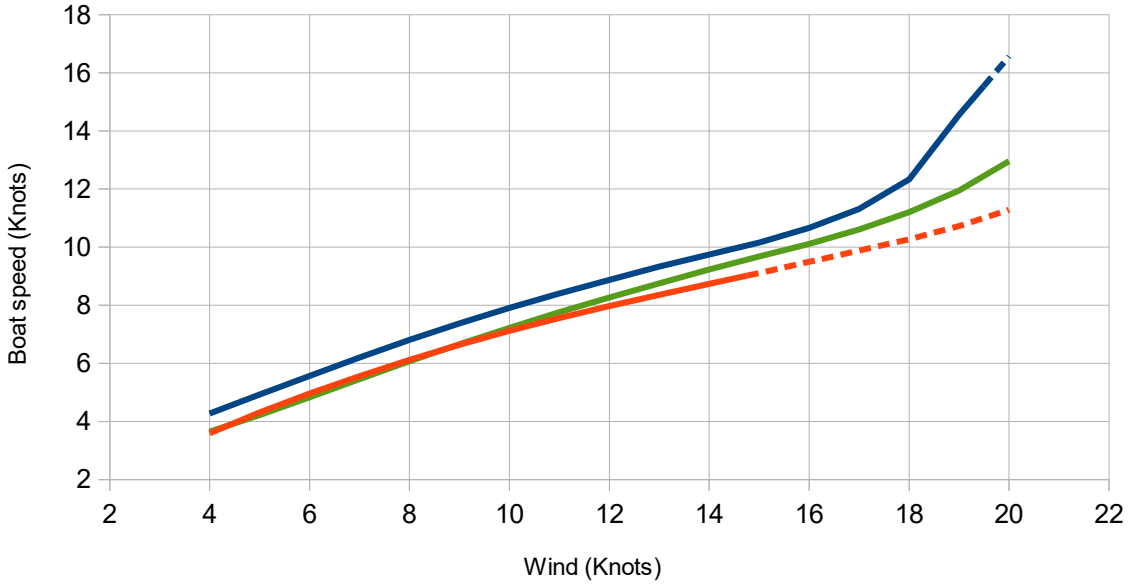
Spi			
CL Spi	CD Spi	Ft spi (kN)	Fs spi (kN)

2.4 Figures about Boat speed, Heel angle, Flat optimum, Righting Moment, Drag

The figures are provided automatically, here below presented with the boat C1 as example. The dashed lines are used when the windward hull displacement is less than 30% of the total, indicating that it is a more tricky sailing which requires either more attention from the crew or a sail area reduction.

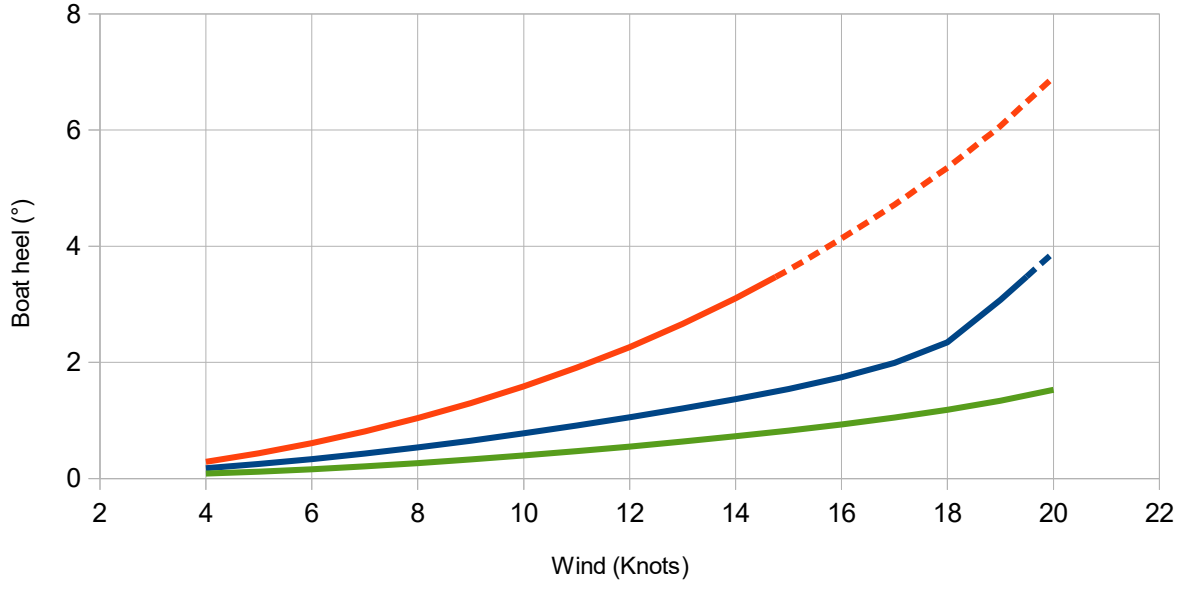
SA-VPP Cata : Speed results

Red : upwind ; Blue : reaching twa 90° ; Green : downwind with spi twa 135°
Continue lines : %D windward hull > 30% ; Dashed lines : %D windward hull < 30%



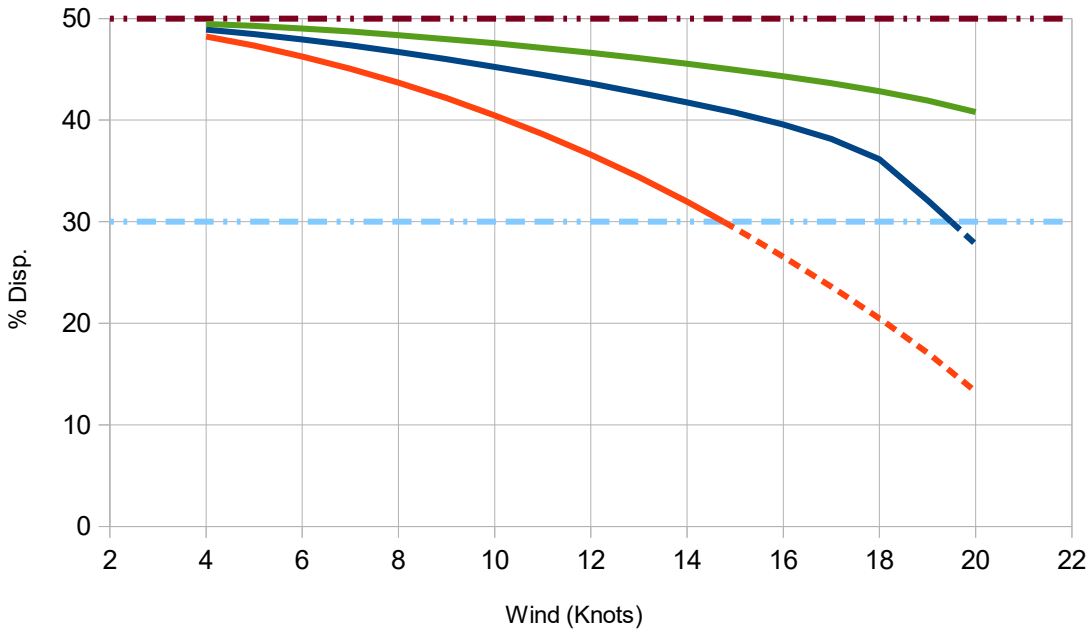
SA-VPP Cata : Heel results

Red : upwind ; Blue : reaching twa 90° ; Green : downwind with spi twa 135°
Continue lines : %D windward hull > 30% ; Dashed lines : %D windward hull < 30%

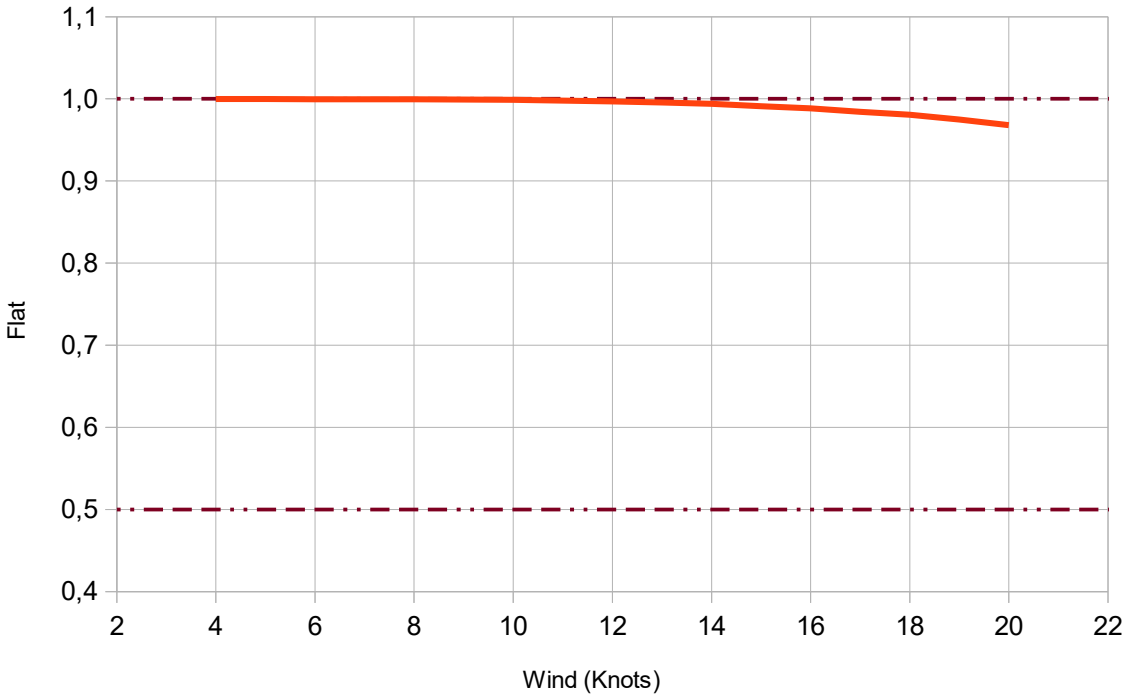


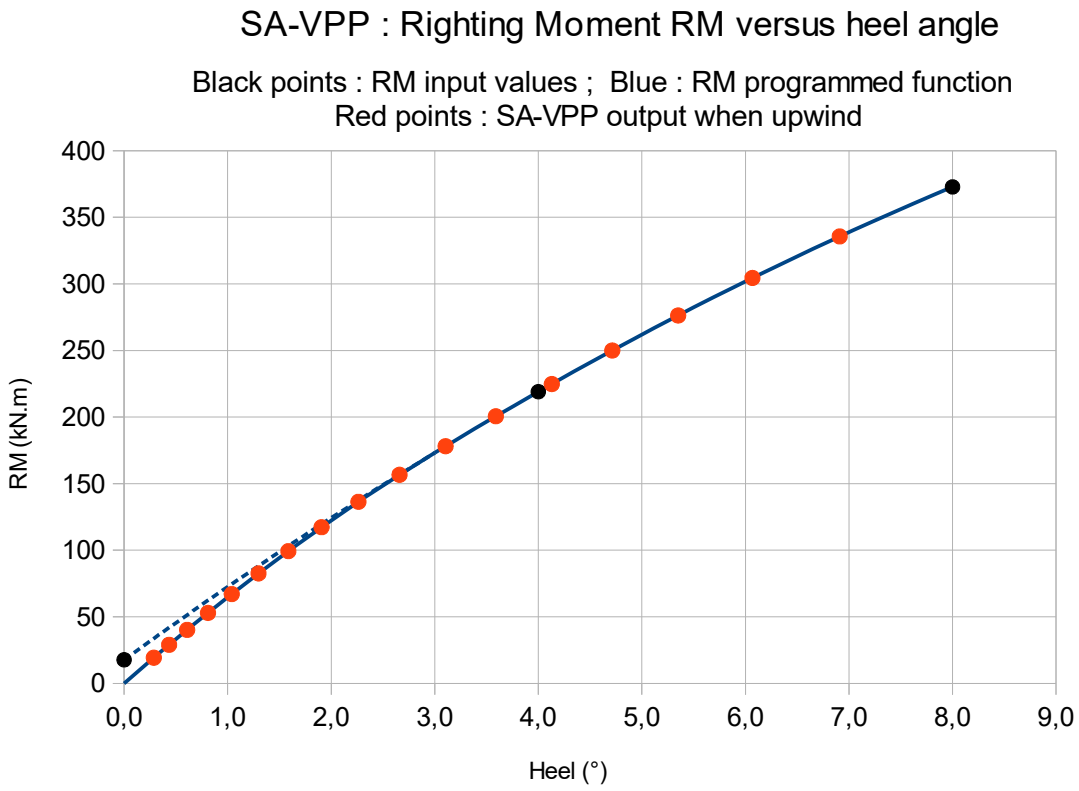
SA-VPP Cata : % of Displacement supported by the windward hull

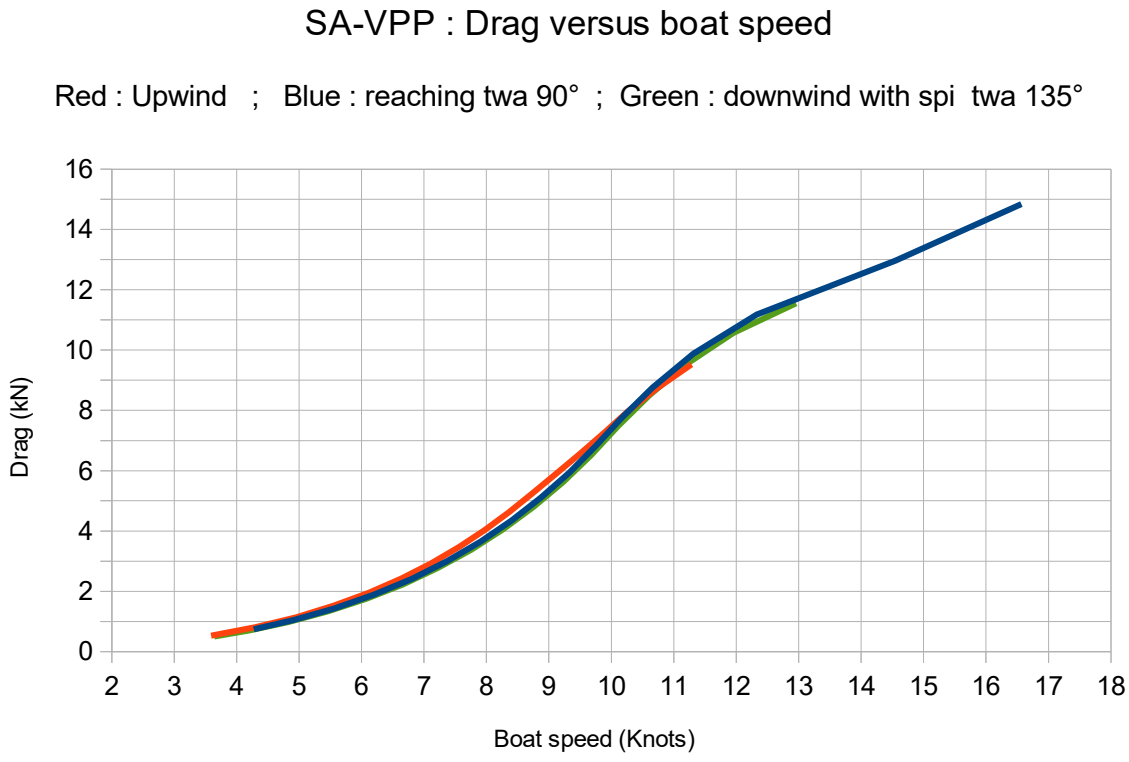
Red : upwind ; Blue : reaching twa 90° ; Green : downwind with spi twa 135°

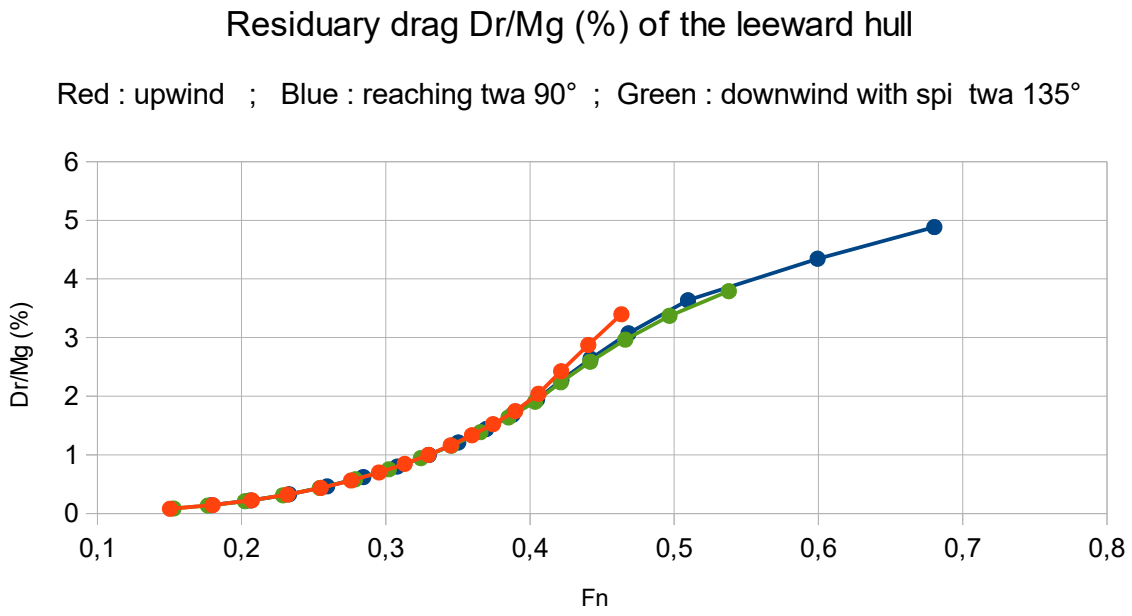


SA-VPP cata : Optimal Flat when upwind



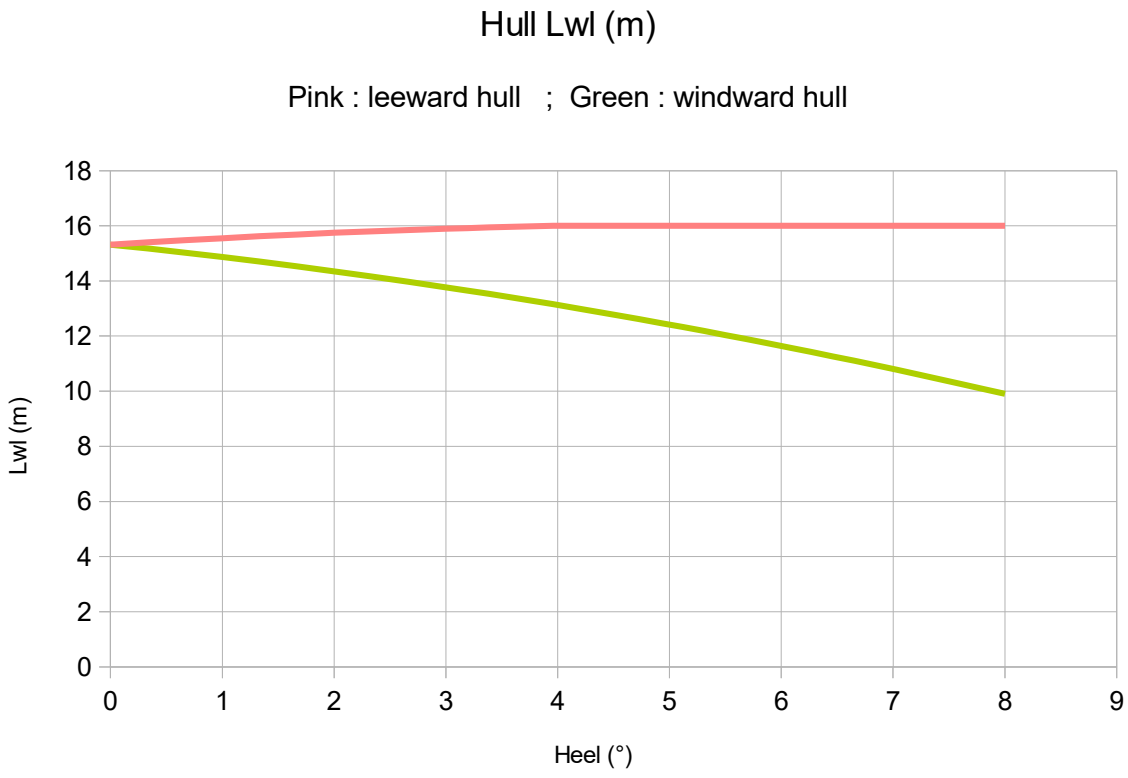

SA-VPP : Righting Moment RM versus heel angle
Black points : RM input values ; Blue : RM programmed function
Red points : SA-VPP output when upwind
RM (kN.m)
400
350
300
250
200
150
100
50
0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
Heel (°)


SA-VPP : Drag versus boat speed
Red : Upwind ; Blue : reaching twa 90° ; Green : downwind with spi twa 135°
Drag (kN)
16
14
12
10
8
6
4
2
0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Boat speed (Knots)



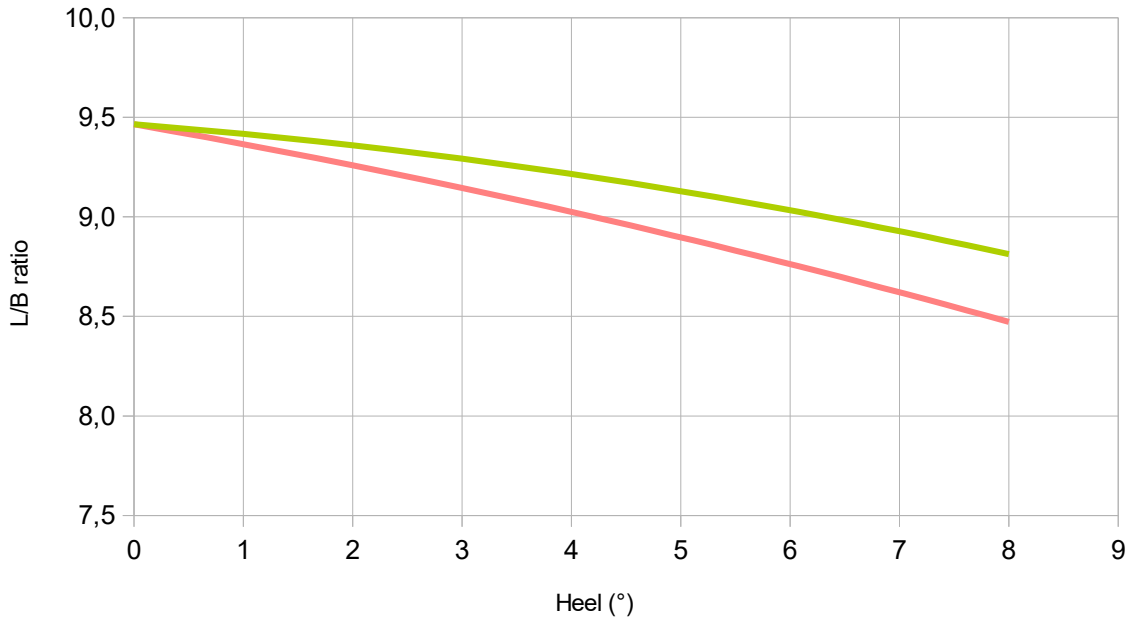
2.5 Other figures about parameters of each hull for the heeled catamaran

These figures represent for the C1 case the programmed functions of these parameters in the VPP, based on the data enter for the 3 heels in the input table :



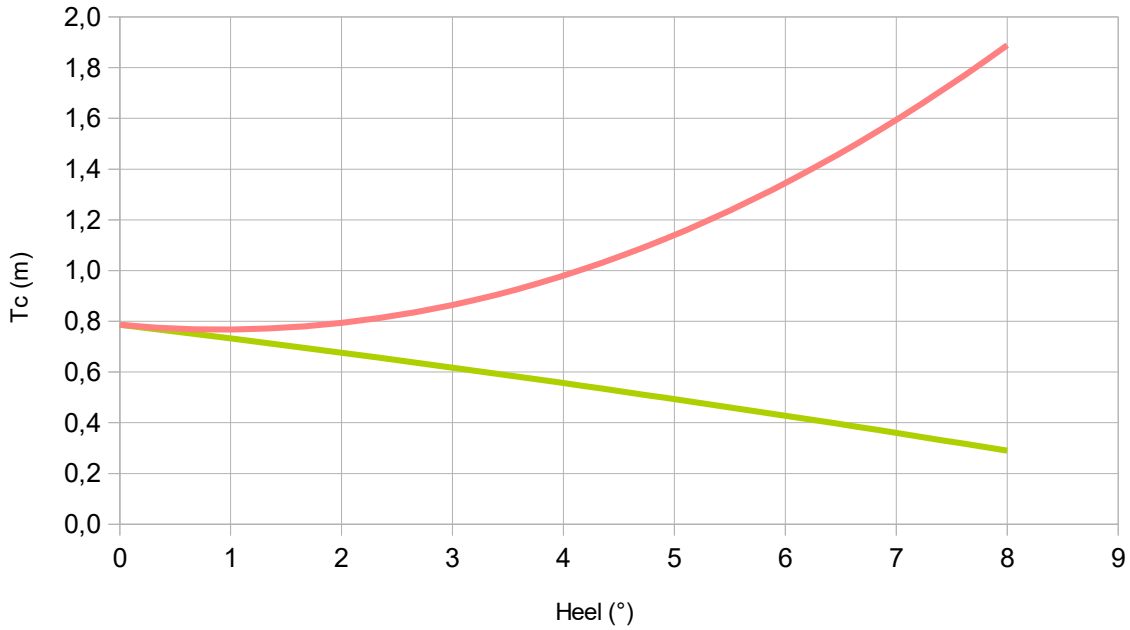
Hull Lwl/Bwl

Pink : leeward hull ; Green : windward hull



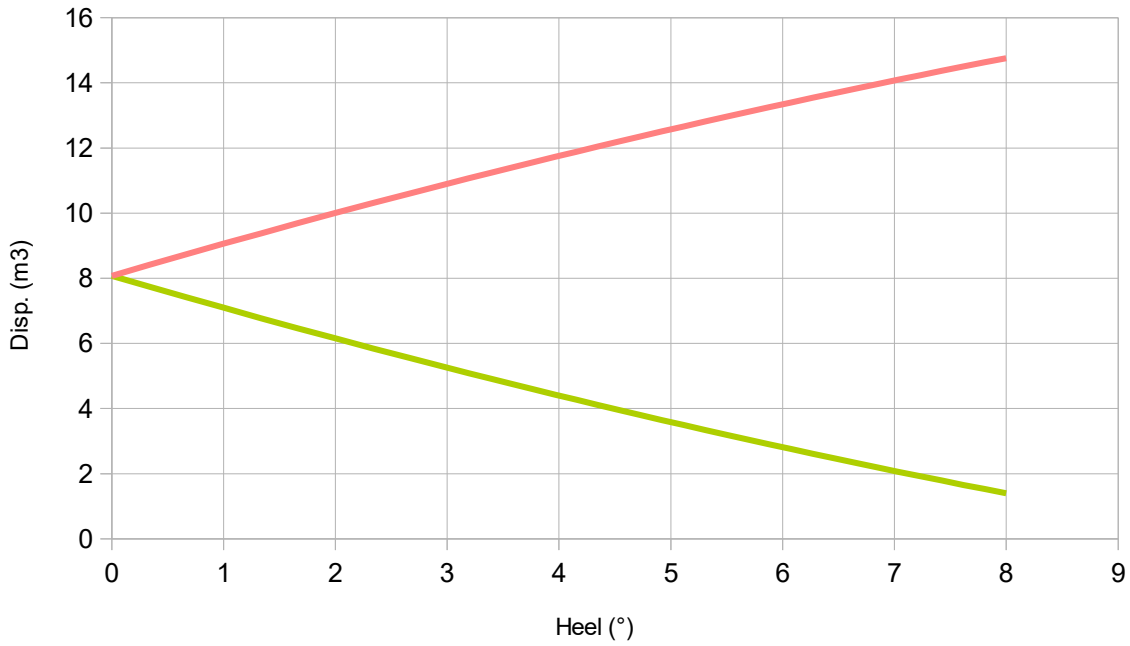
Hull bodies draft Tc (m)

Pink : leeward hull ; Green : windward hull



Hull displacements (m3)

Pink : leeward hull ; Green : windward hull



Sw hull bodies

Pink : leeward hull ; Green : windward hull