Corbin 39 - VPP issue and results - as for 24 05 2020

Summary

Introduction

We have adressed the performance issue with both an home made Velocity Prediction Program named SA-VPP and the results of USVPP for the ship at displacement D 14000 kg and Zg 0,038 m, i .e. the « average » ship data adopted in the stability issue to compute the GZ curve and the righting moment available versus the heel angle, and for the various existing sailplans. The common input data are detailed in annex1.

We first took adavantage of the comparison with USVPP output data to improve and calibrate the home made SA-VPP. We put our first concern on the reliability of the simulations with regarding the variation of main input parameters : sail surface, height of the center of effort and aspect ratio (linked to the Lead issue)

We have considered 3 typical sailing configurations : upwind, beam reaching (true wind angle twa 90°), downwind (twa 140°)

We also investigated the influence when upwind of the true wind angle (twa), The « Flat » parameter (reflecting the ability to flatten the sails), the sail surface itself, i.e. the reefing and when it appears more profitable.

The input data :

D 14 t , RM (from the stability study, Zg 0,038 m) + Crew 150 kg at 1,45 m
(For USVPP >> Crew 584 kg at 1,46 m is programmed inside)

D 14 t , RM (from the stability study, Zg 0,038 m) + Crew 150 kg at 1,45 m
(For USVPP >> Crew 584 kg at 1,46 m is programmed inside)

All input data are given in Annex 1

The Velocity Prediction Programm VPP tools used for this investigation

Two VPPs have been used :

- an home made one, named SA-VPP, SA standing for Spreadsheet Application, as this VPP has been developed within this universal framework,
- The USVPP, developed for IMS rating purpose

The advantage of SA-VPP is to master all the parameters and formulations involved, including the ones that are automatically adjusted by USVPP and so out of control for the users, like the "Flat" (degree of camber of the sails), the Reefing, the additionnal righting moment due to the crew, ... More detailed about the formulations involved in SA-VPP are given in Annex 2.

The main process consists, for each wind force and direction, of iterations on Boat Speed and Heel angle up to reach equalities for : thrust = drag and righting moment = heeling moment. Within SA-VPP, it is a manual iteration (but not too much time consuming with a bit of training).

The approach :

– USVPP results for the Sloop mk2 49' sailplan are used to fine tuned SA-VPP internal coefficients (for the sail forces mostly), then we did the comparison with the Ketch mk1 and the 3 mk1 51' version which appears quite good.

– With SA-VPP and for upwind conditions, we did series of computation to investigate the influence of the "Flat" parameter, the trus wind angle "twa" one, the reefing "R" one. Because the optimum efficiency results from a combination of these 2 to 3 (when reefing is worth) parameters.

– Using SA-VPP, we give the estimated speed and heel angle for the 7 sailplans and 3 typical sailing conditions : upwind, beam reaching (twa 90°), downwind without spi (twa 140°), and for wind speed from 4 to 20 Knots.

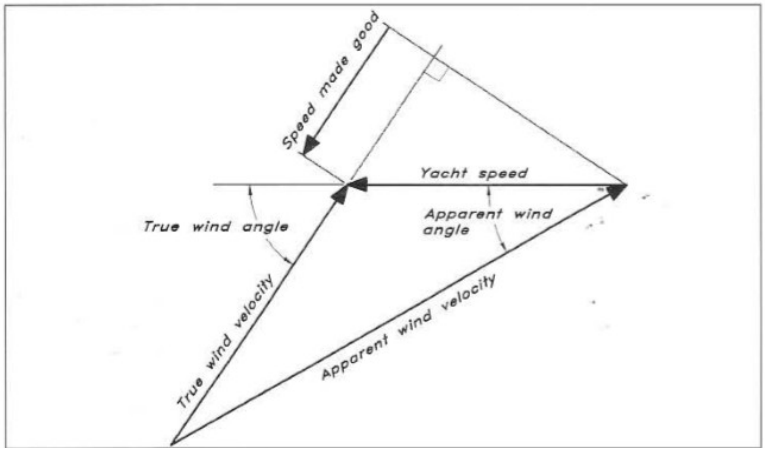
– Comparison of the sailplans performance with comments,

Comparison SA-VPP and USVPP with 5 sailplans

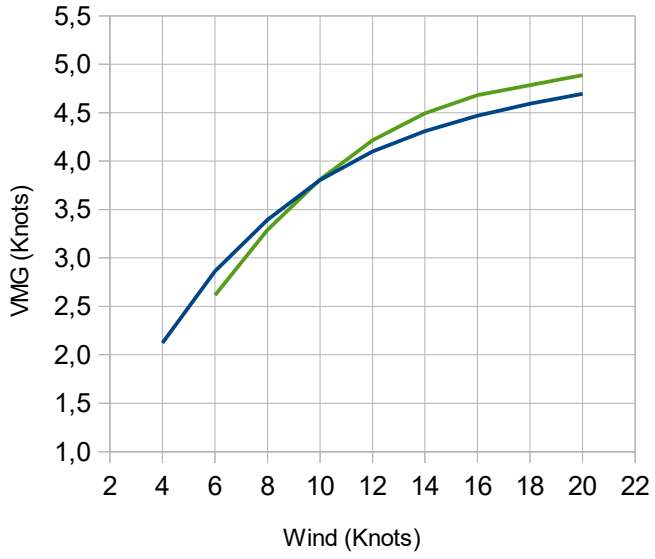
Done for 5 sailplans (mk2 49', Ketch mk1, mk1 51' without bowsprit, with bowsprit, boom shortened) and 3 sailing conditions upwind, beam reaching twa 90°, downwind twa 140° without spi . To note that the righting Moment used in USVPP is slightly more important than the one adopted in SA-VPP because USVPP, being rating oriented, considers (automatically) an extra RM due to a crew of (in the Corbin 39 case) ~ 584 kg sit winward at ~ 1,46 m. For the SA-VPP, considering its blue water short-handled orientation, we considers an extra RM due to a crew of

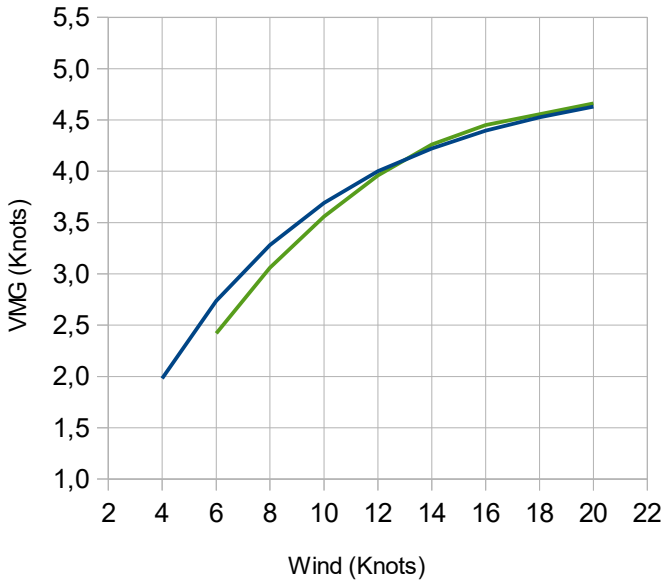
150 kg sit windward at 1,45 m, for the upwind and beam reaching conditions. No extra RM considered for downwind twa 140° conditions. Consequently, USVPP results usually shows a bit less heel angle and a bit more power by breeze.

For the comparison upwind, we add the Velocity Made Good (VMG) curve, i.e. the best speed in projection of the wind direction. It is obtained by a combination of twa and Flat, and this combination can be slightly different within each VPP tool, being sensitive to the more or less sophisticated formulations involved. Figure thanks to « Principles of Yacht Design » by R. Larsson & E. Eliasson) :



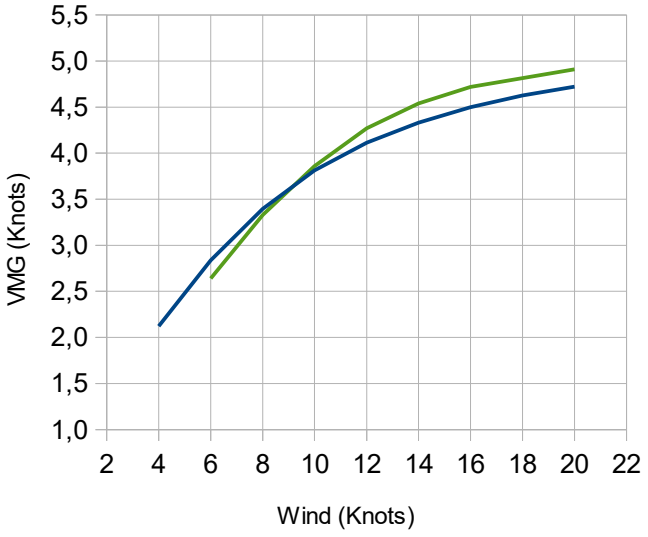
The comparison when upwind on calm water (no waves added drag taken into account)





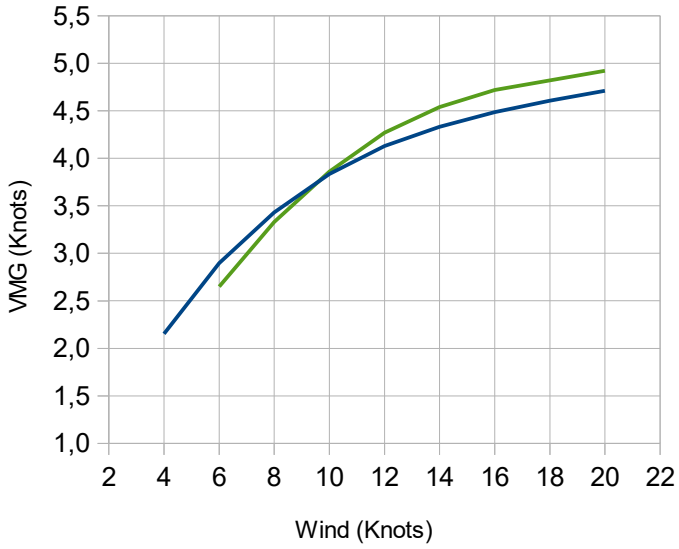
Sloop mk1 51' - VMG when upwind

Blue : VPP ; Green : USVPP



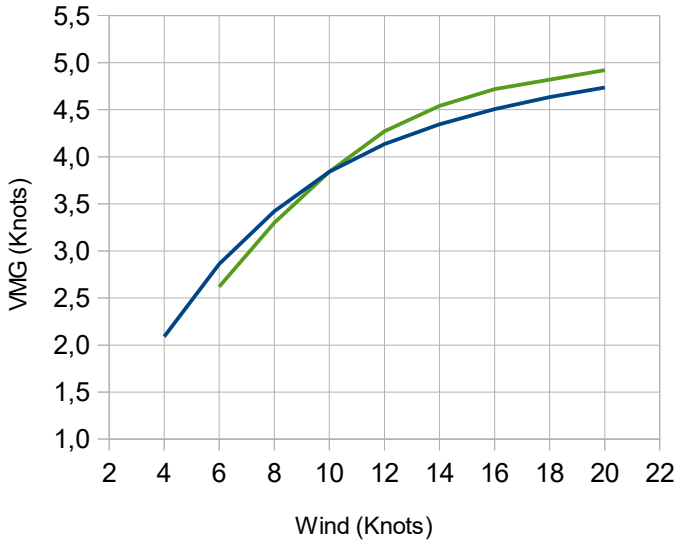
mk1 51' bowsprit - VMG when upwind

Blue : VPP ; Green : USVPP



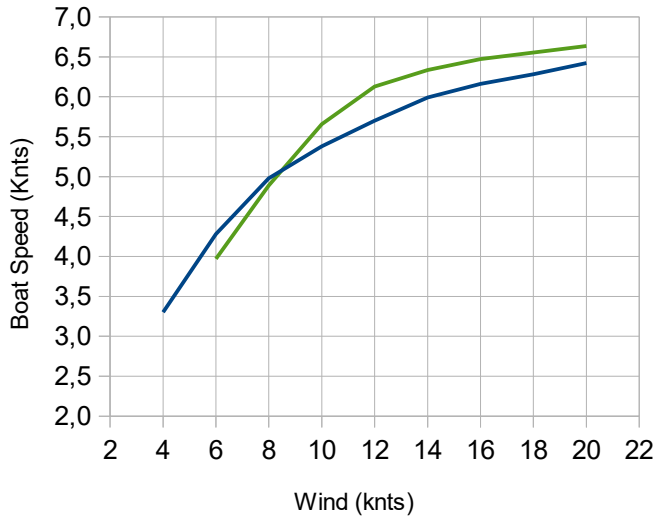
mk1 51' boom shortened - VMG when upwind

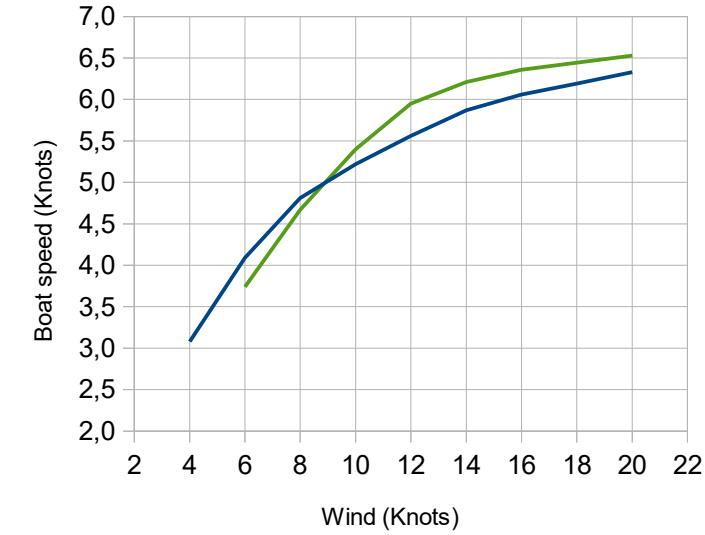
Blue : SA-VPP ; Green : USVPP

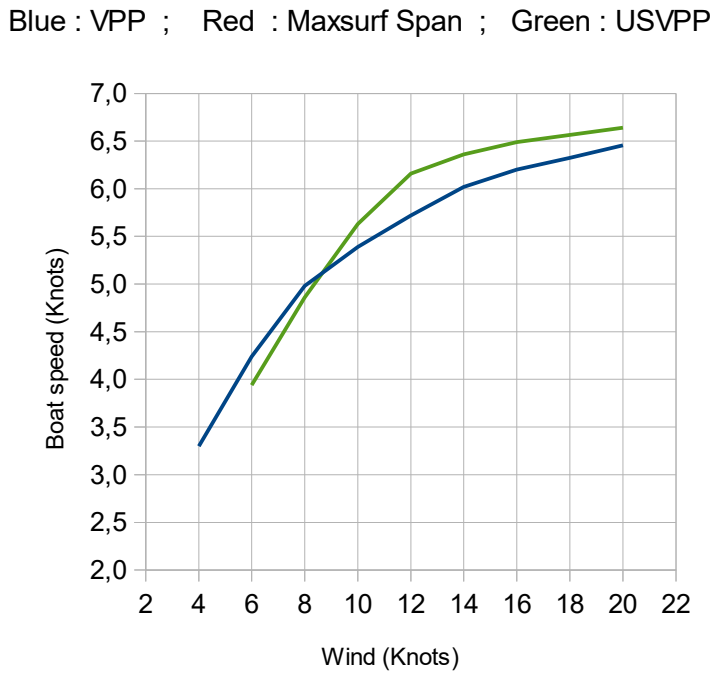


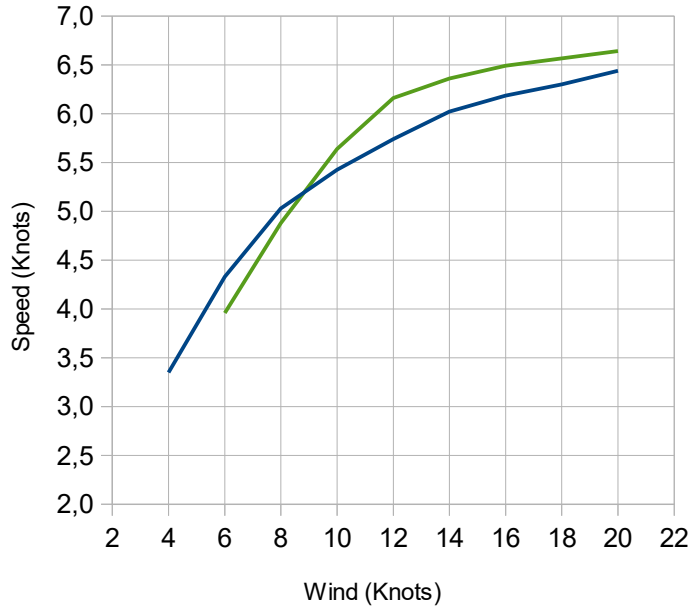
>>> in average, SA-VPP leads to more VMG by light winds and less by breeze than USVPP.

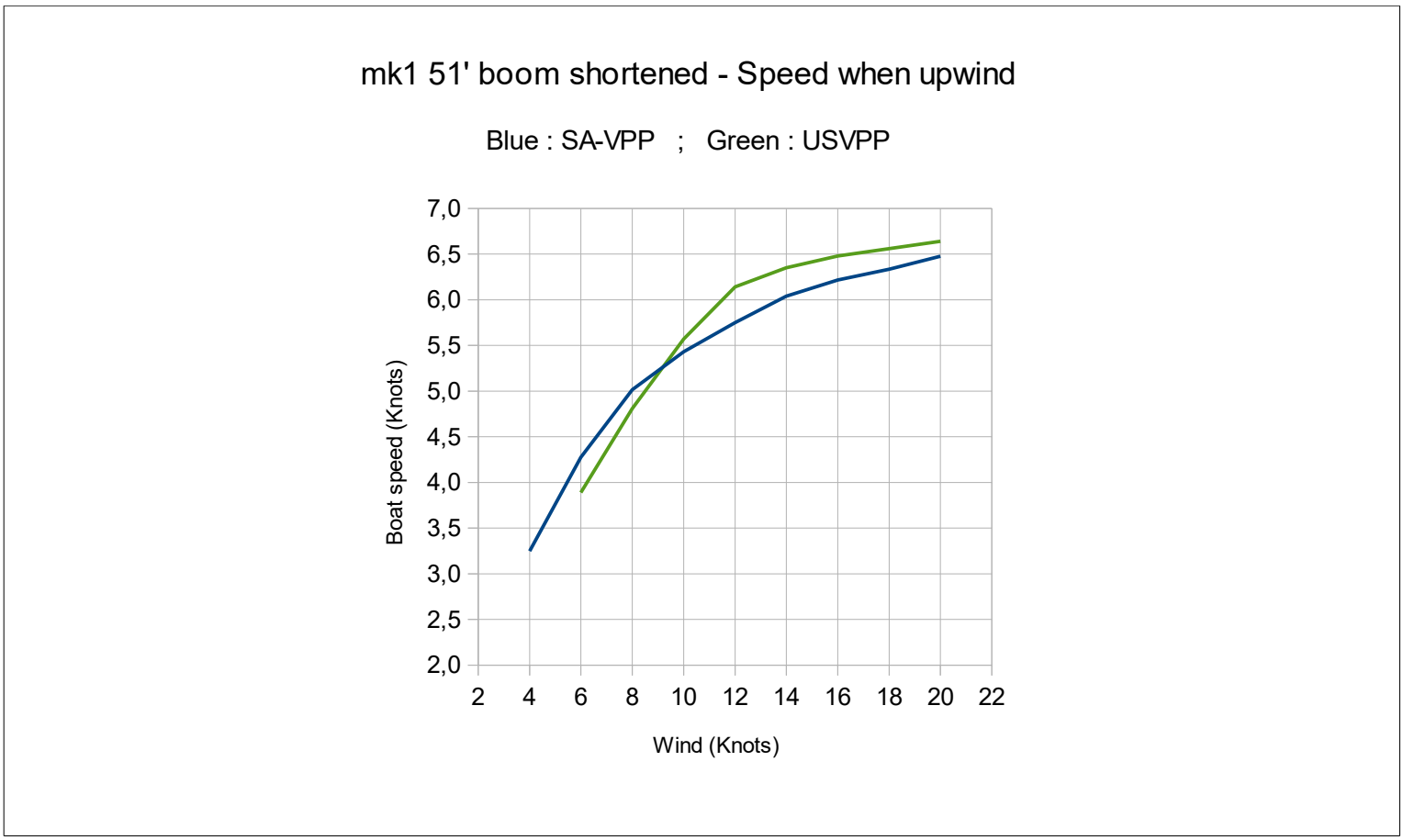
The corresponding boat speeds are :







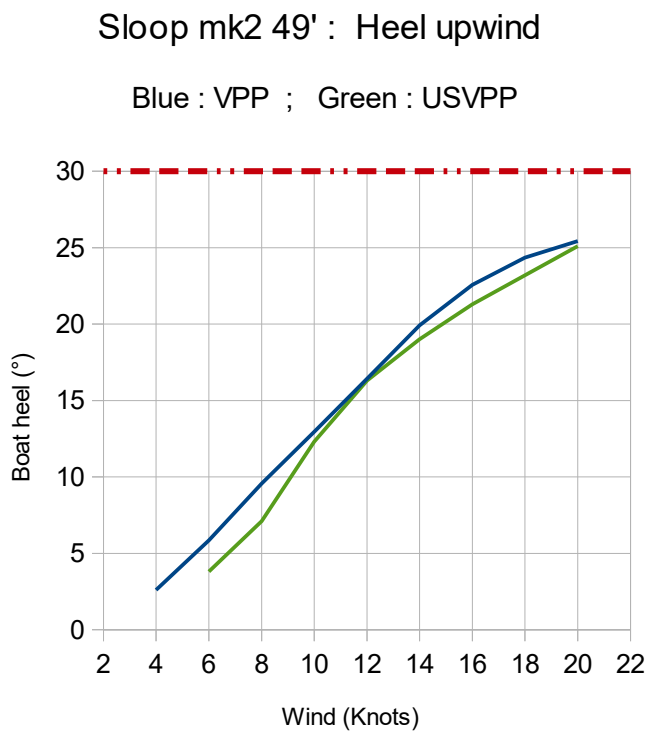


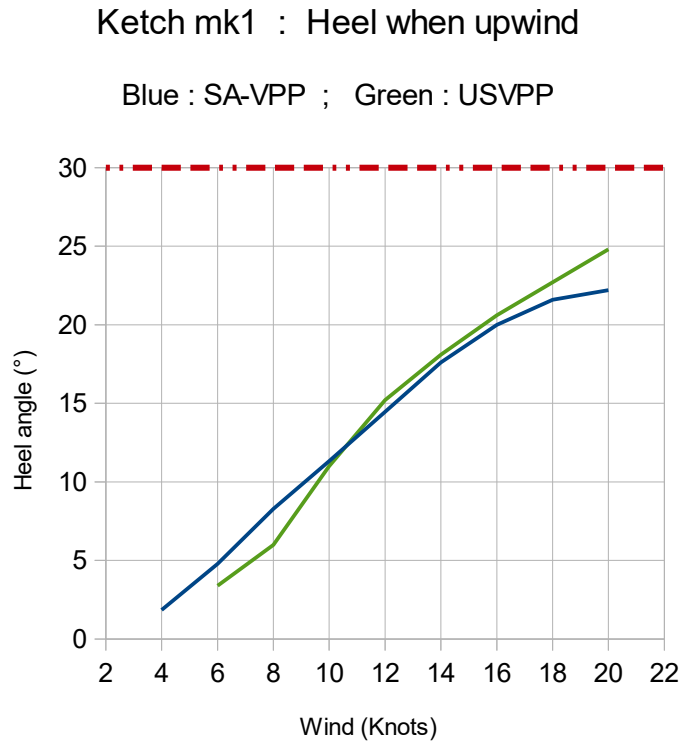


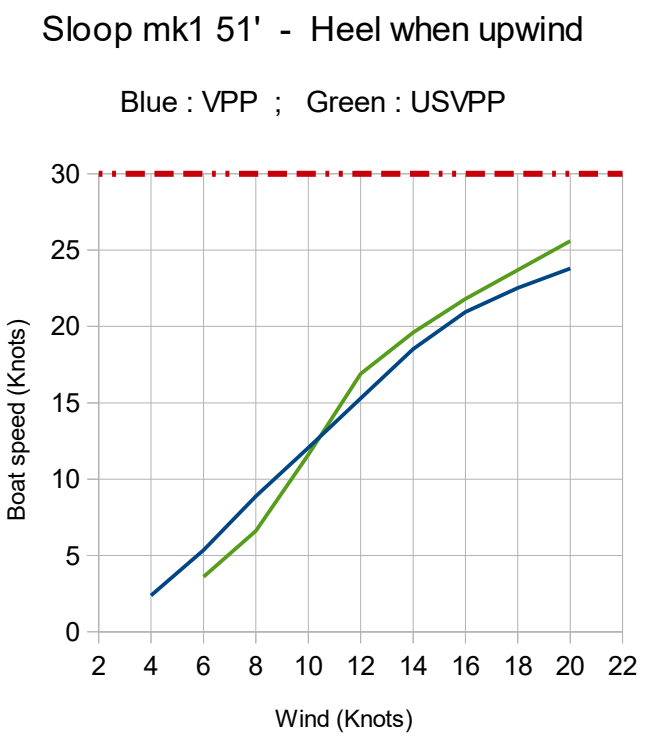
>>> the differences in boat speeds, which looks more important than from the VMG comparison, are partly due to slightly higher twa(s) automatically adopted by USVPP / the ones pre-set in SA-VPP :

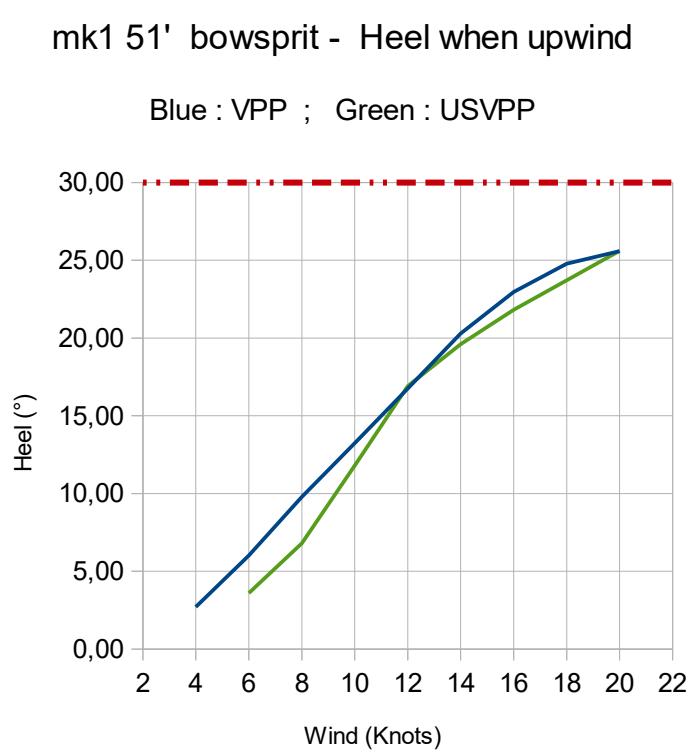
Upwind	SA-VPP all sailplans	USVPP mk2 49'	USVPP Ketch mk1	USVPP mk1 51'	USVPP mk1 51' bs	USVPP mk1 51'boom
Vw10 (Knots)	**twa** (°)	**twa** (°)	**twa** (°)	**twa** (°)	**twa** (°)	**twa** (°)
4	50,00					
6	48,00	48,80	49,90	47,90	48,00	47,70
8	47,00	47,70	49,10	46,80	46,90	46,70
10	45,00	47,60	48,70	46,70	46,80	46,40
12	44,00	46,50	48,30	46,10	46,10	46,00
14	44,00	44,80	46,70	44,40	44,40	44,40
16	43,50	43,70	45,60	43,30	43,30	43,30
18	43,00					
20	43,00	42,60	44,50	42,30	42,30	42,30

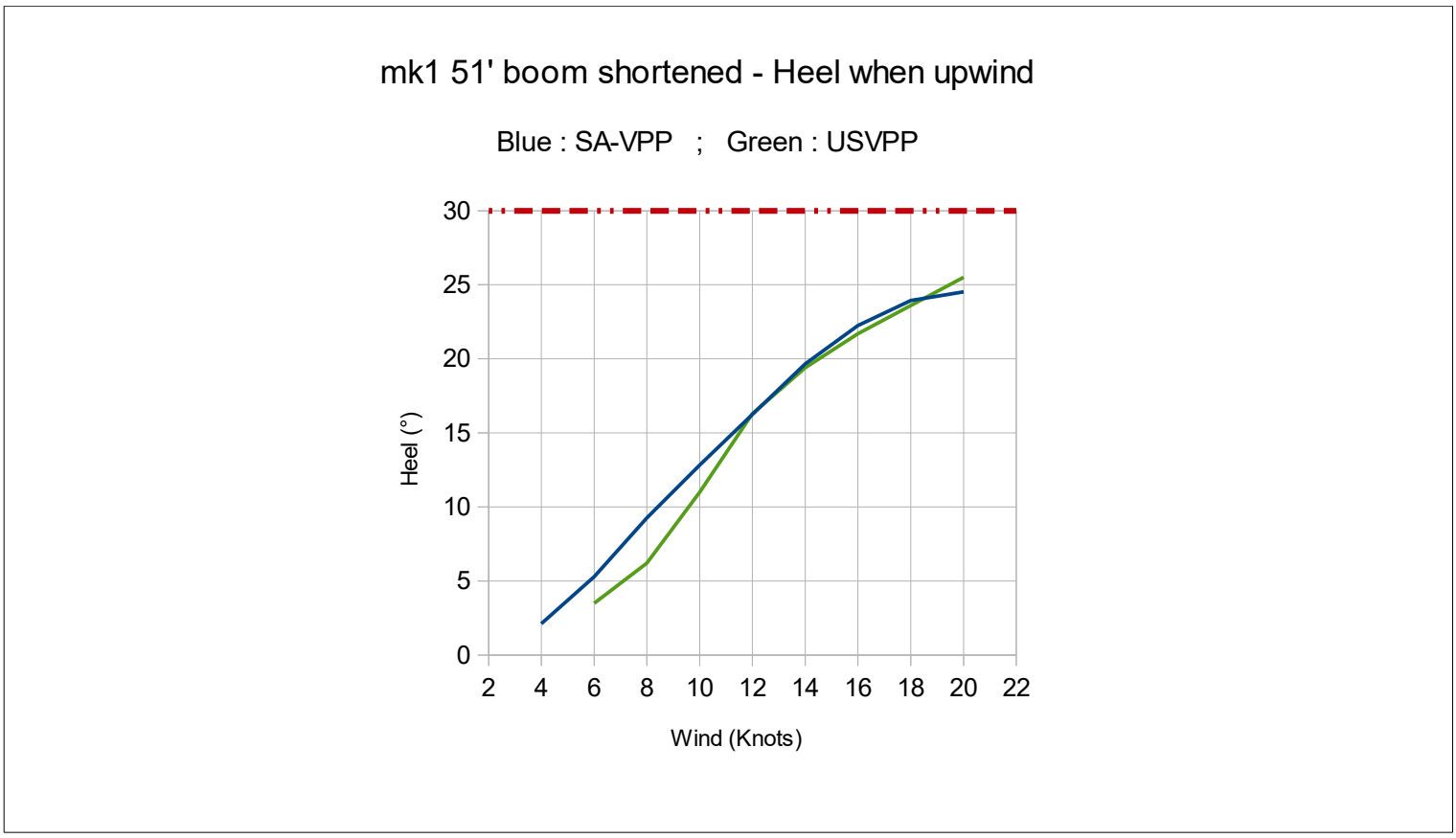
The corresponding heel angles are :











>>> good concordance in average

Some specifical considerations when sailing upwind :

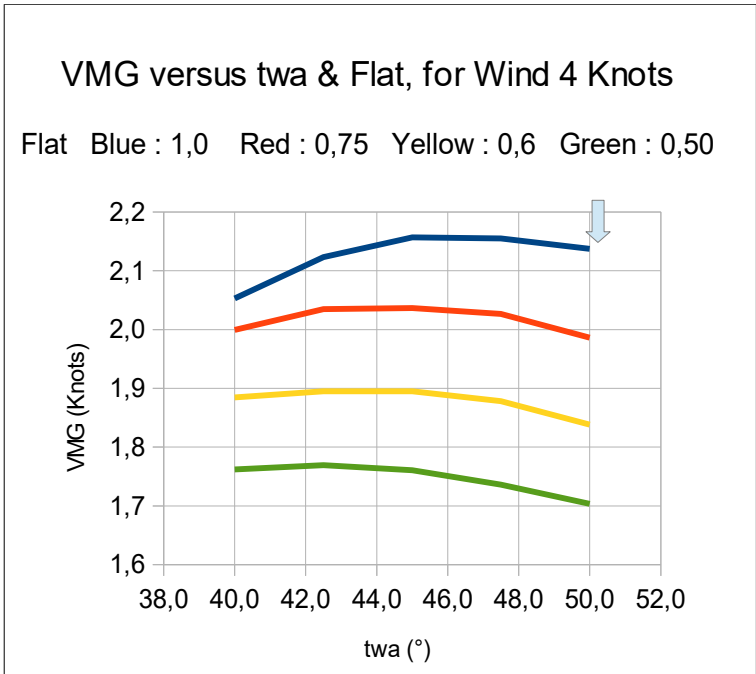
It is the most delicate case to deal with numerical tools as in the reality because, the real objective being the best speed in projection into the wind direction (the VMG), the parameters to reach this best cannot be fixed a priori :

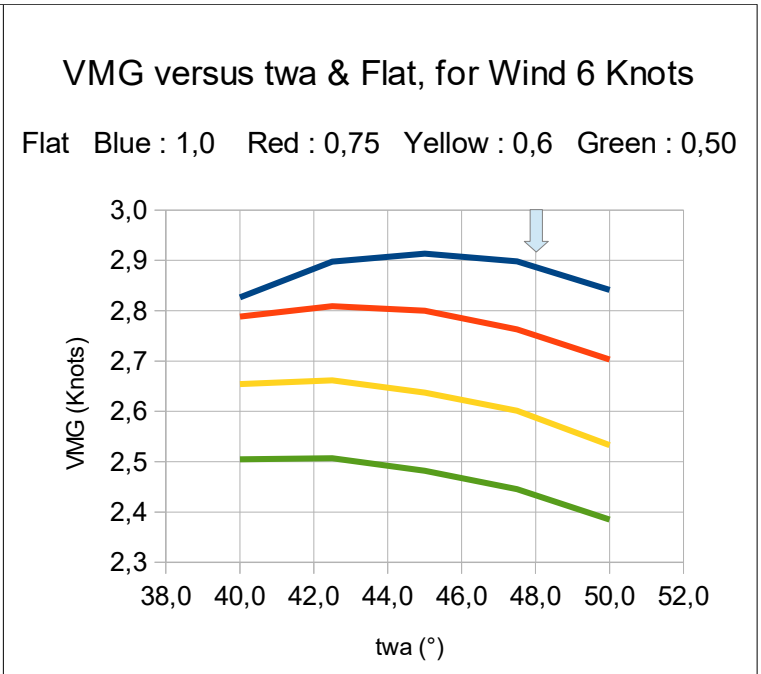
- the true wind angle twa : with a smaller twa, the boat speed projection can be better but in the same time the boat speed decrease
- the Flat parameter, i.e. the ability to flatten the sails (to reduce the camber) in order to improve the lift/drag CL/CD ratio, leading to more forward thrust and less side force (i.e. less heel)
- the reefing parameter R, becoming the best choice from a certain wind force and/or heel angle

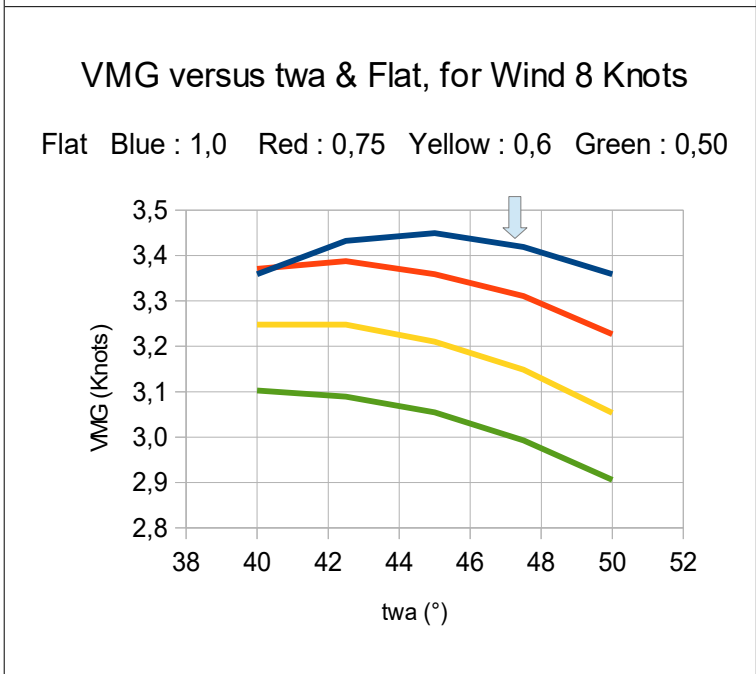
The usual VPPs automatically propose the best compbination twa, Flat and if necessary R when upwind sailing, which prevents the user to investigate more systematically the relative influence of these 3 parameters. With SA-VPP it is possible to compute such series, which help show and appreciate these influences (Done with the mk2 49' sailplan)

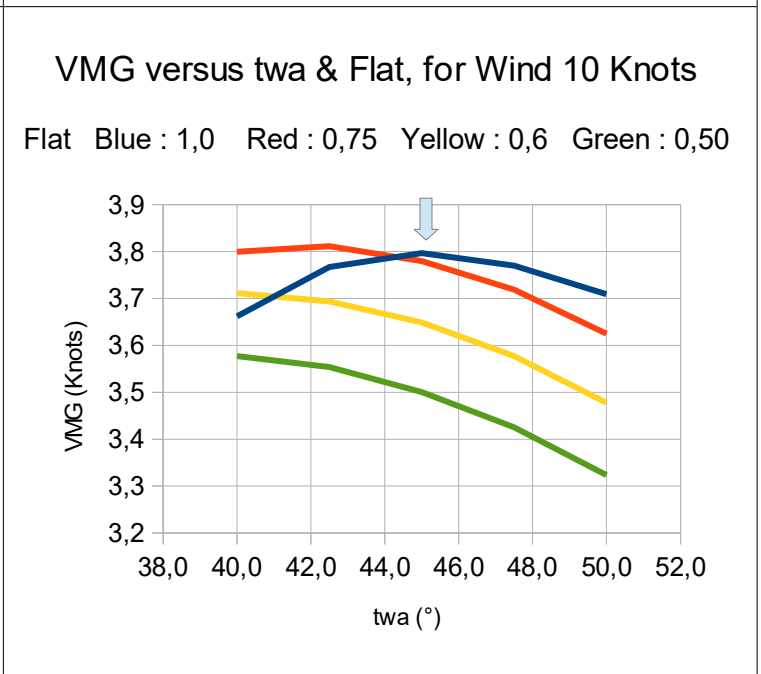
True wind angle (twa) influence when sailing upwind

The serie was performed for twa from 50° to 40° , i.e. where usually is the optimum VMG. With 4 Flat values ((1,0 0,75 0,6 0,5), i.e. from 1 (cambered sails for light winds, >> CL 1,5) to 0,5 (maximum flattening when breeze wind, >> CL 0,75). The following curves shows the combined influence of twa and Flat, the top of the higher curve corresponds to VMG max, and that allows to check the relevance of ***the twa pre-settings*** adopted to alleviate the computations for the 7 sailplans : they are intentionaly choosen on the right side of the VMG very max in order to have a bit more twa and so more speed on the water (they ***are showed with a blue arrow in the figures here below.***)



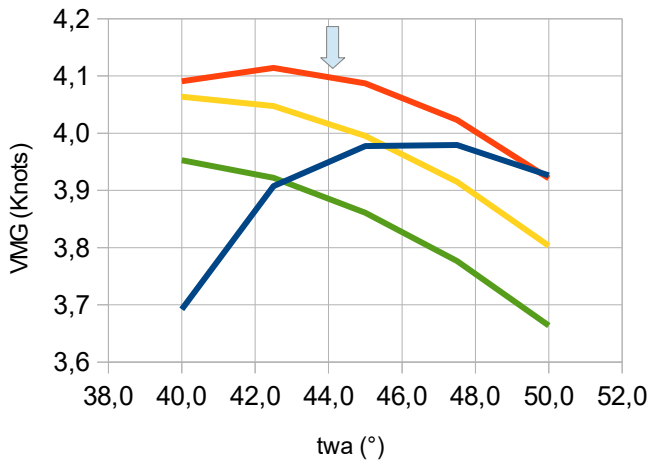






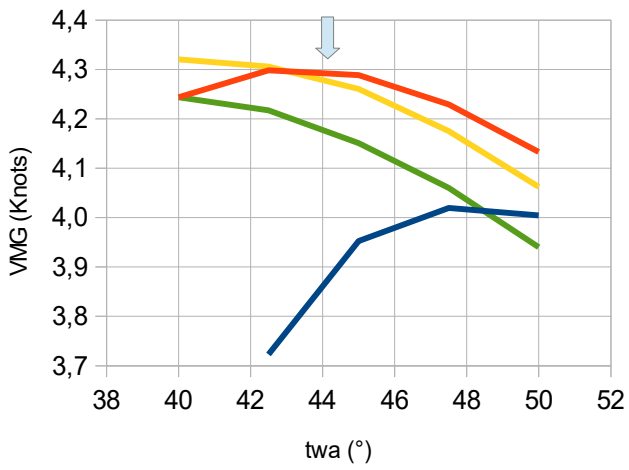
VMG versus twa & Flat, for Wind 12 Knots

Flat Blue : 1,0 Red : 0,75 Yellow : 0,6 Green : 0,50



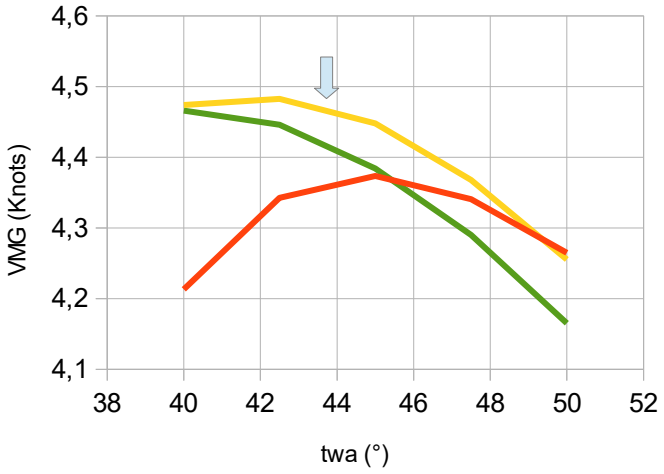
VMG versus twa & Flat, for Wind 14 Knots

Flat Blue : 1,0 Red : 0,75 Yellow : 0,6 Green : 0,50



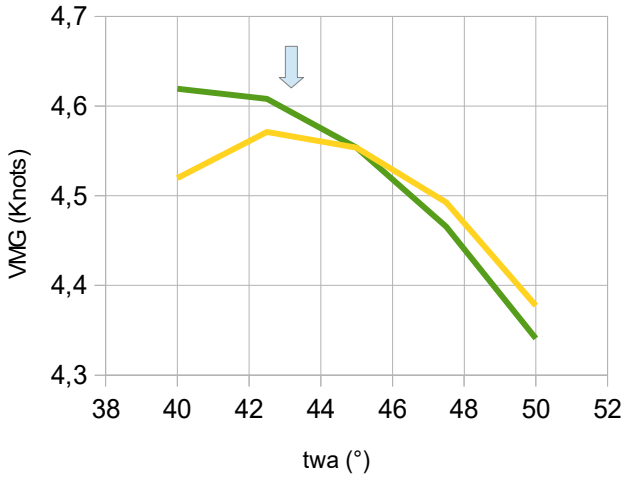
VMG versus twa & Flat, for Wind 16 Knots

Flat Blue : 1,0 Red : 0,75 Yellow : 0,6 Green : 0,50



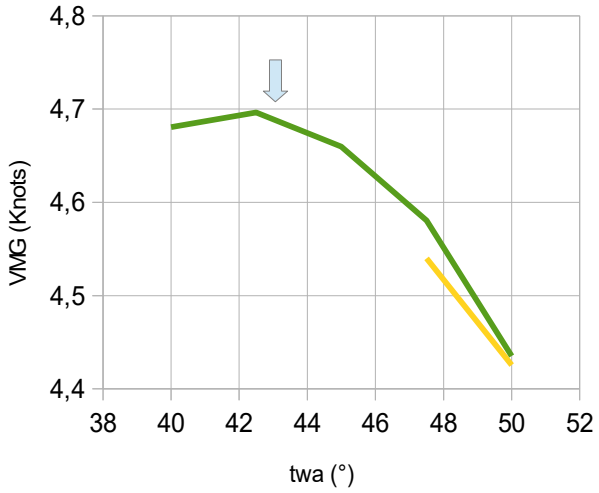
VMG versus twa & Flat, for Wind 18 Knots

Flat Blue : 1,0 Red : 0,75 Yellow : 0,6 Green : 0,50



VMG versus twa & Flat, for Wind 20 Knots

Flat Blue : 1,0 Red : 0,75 Yellow : 0,6 Green : 0,50



Flat influence when sailing upwind

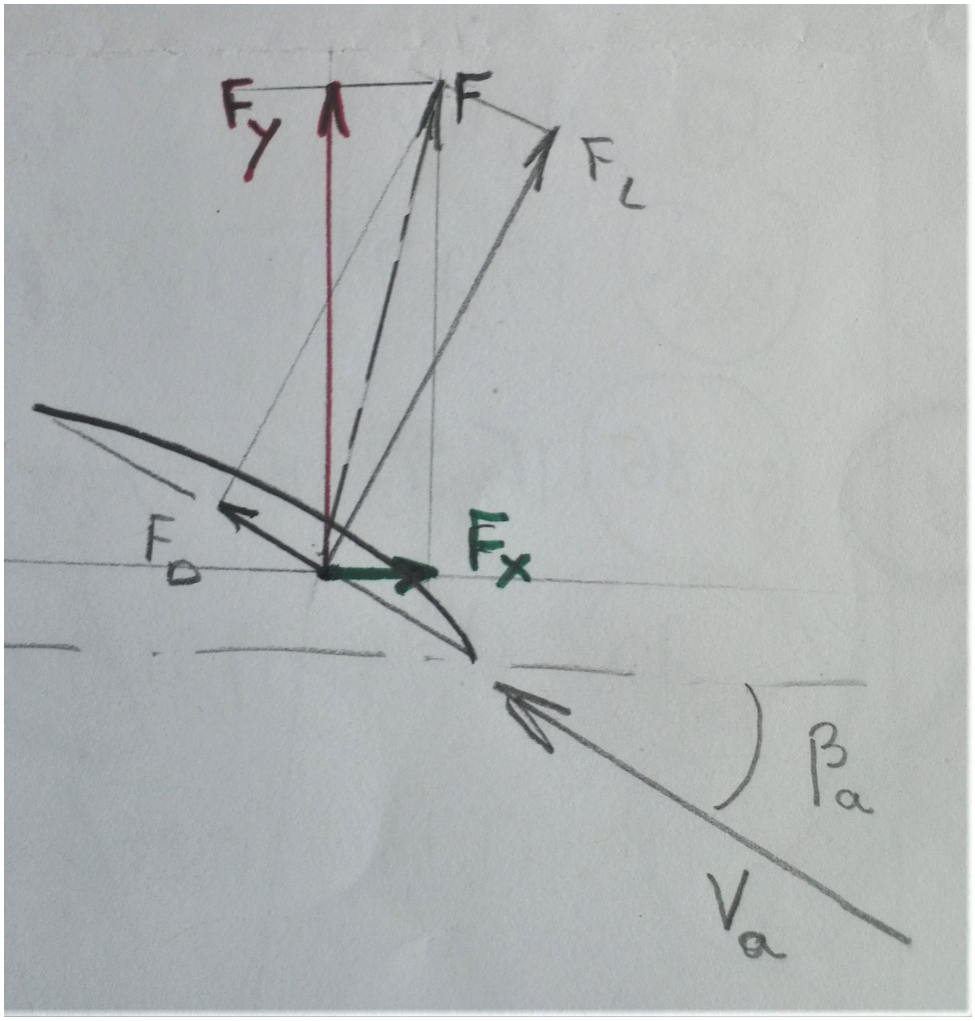
In the VPP formulations, the flattening ability is represented by a coefficient, « Flat », acting directly on CL and indirectly on CD through these basic formulations when considering the sailplan as a wing :

CL = CLmax . Flat

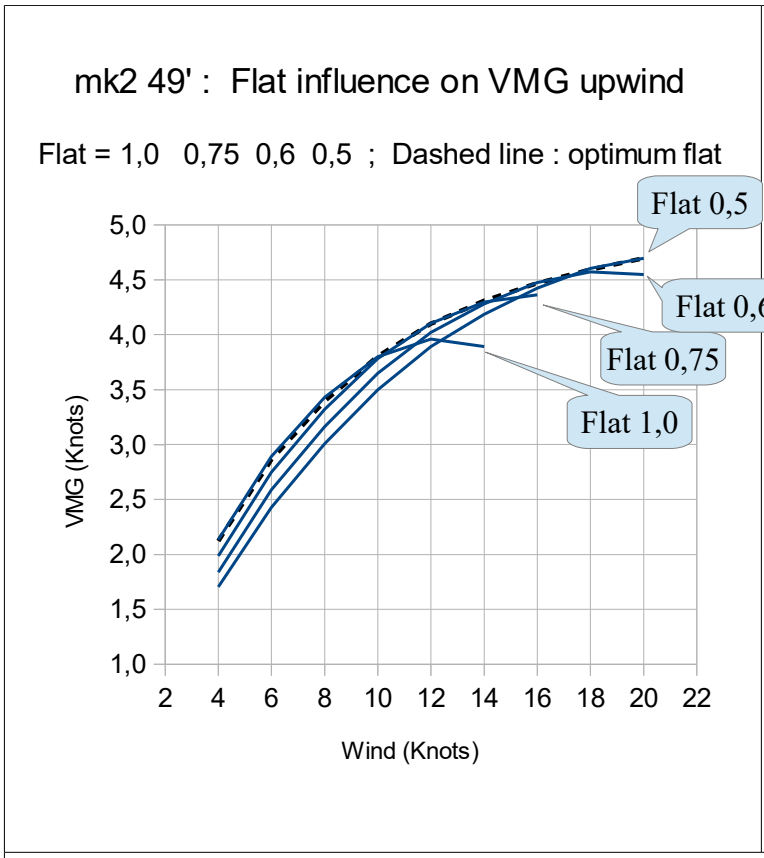
CD = CDo + CL^2 / (π AR)

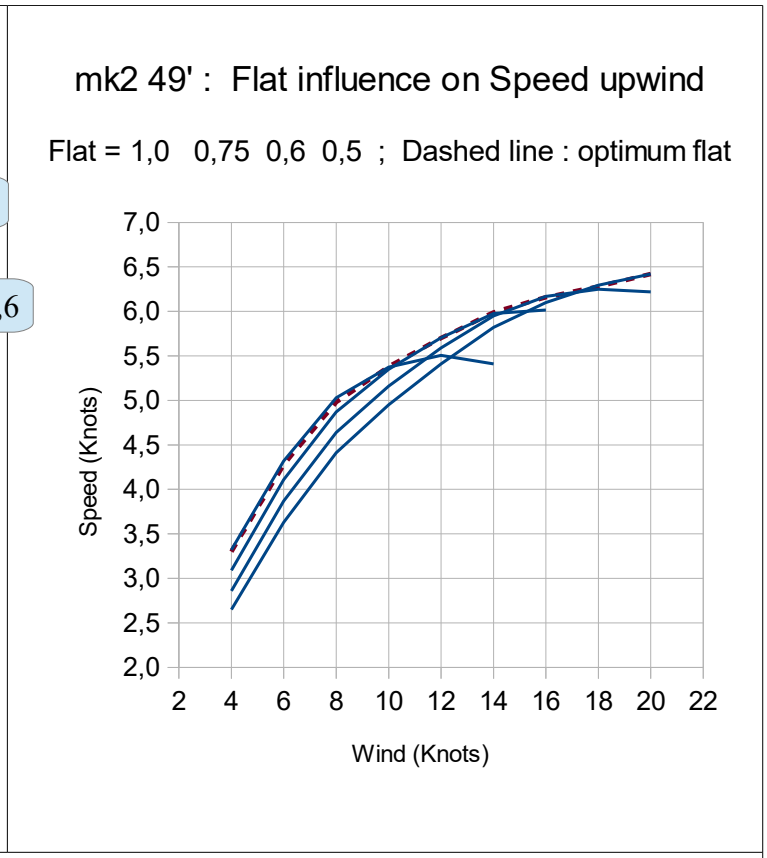
Flat = 1 is the usual value in all sailing conditions except upwind when it is worth to flatten the sails, represented by a Flat coeffcient < 1 but up to a limit 0,5. In most VPP when upwind, CL = 1,5 when Flat = 1 and can be reduced to 0,75 when Flat = 0,5. Although CL is reduced, CD being in CL^2 is a lot more reduced, and so the resultant force F (sketch here below) turns forward and favor the thrust Fx while reducing the side force Fy responsible of the heel.

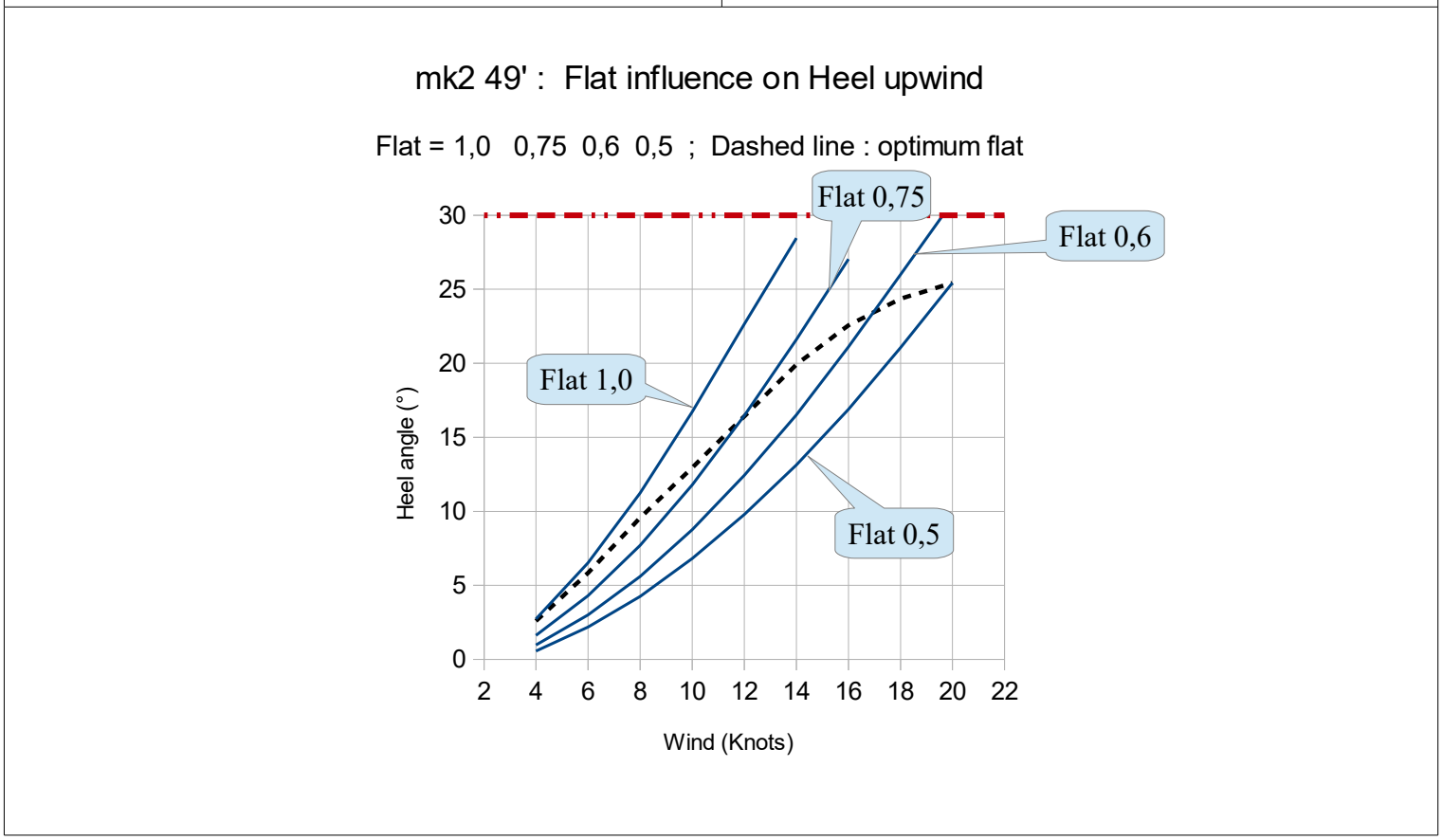
To note also the influence of the global aspect ratio of the sailplan, AR in the formulation, an input data reflecting the more or less slenderness of the sailplan : slenderness reduces the CD value and so leads to a better efficiency upwind.



Flat influence is done with the mk2 49' sailplan :





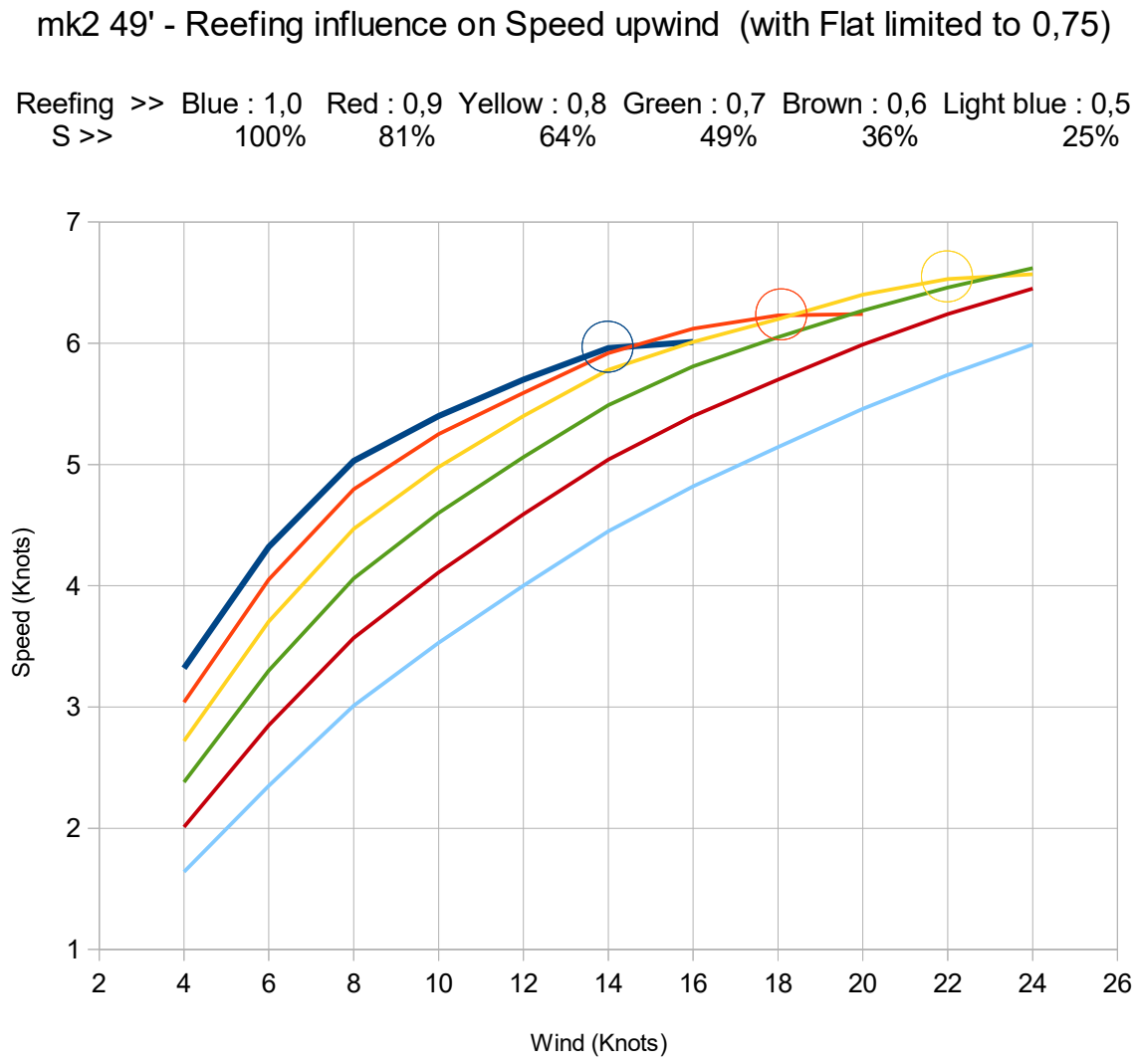


The reefing influence when sailing upwind

Series of simulation with Reefing R input values as here below and within a Flat capability limited to 0,75. Done in order to highlight on the reefing decision making when more flatenning of the sails is no longer possible :

Reefing R	1	0,9	0,8	0,7	0,6	0,5
>> Sails surface	100,00%	81,00%	64,00%	49,00%	36,00%	25,00%

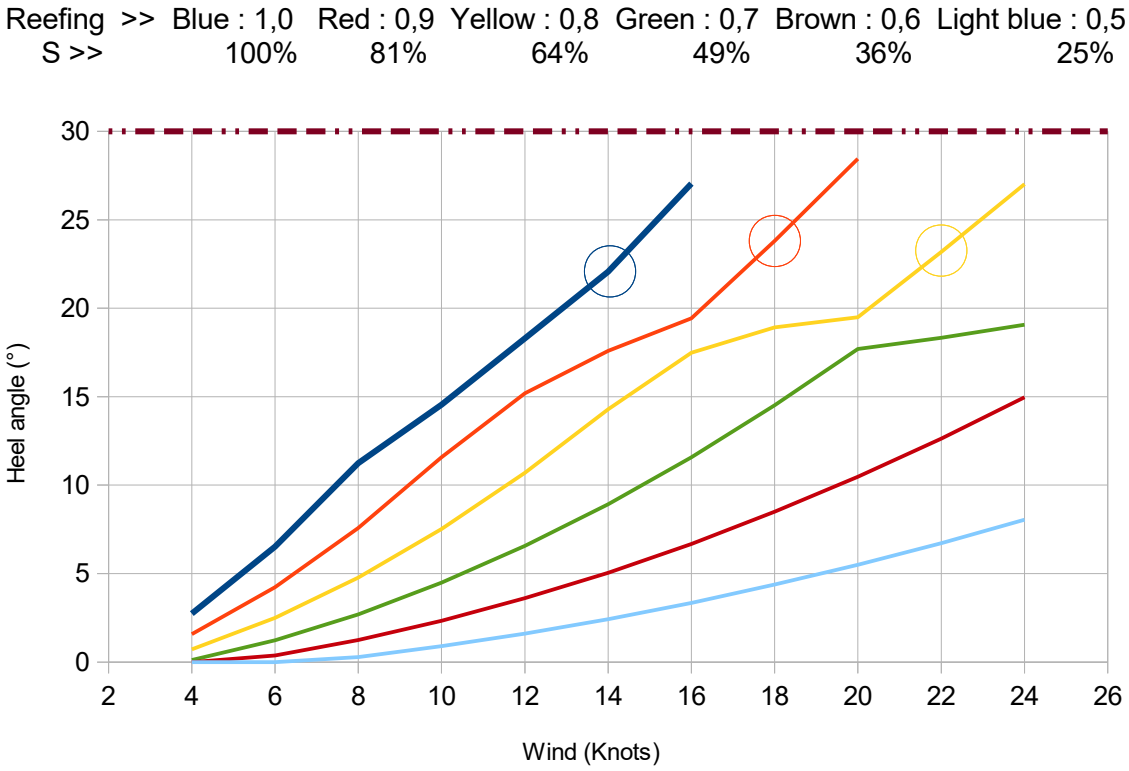
Done with SA-VPP , the mk2 49' sailplan and the twa serie assumed optimum :



>>> The speed figure clearly shows the reefing optimal strategy :

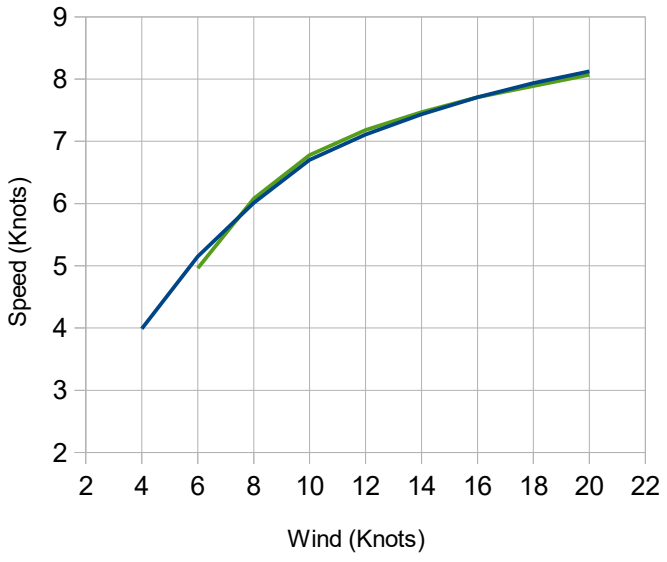
- Up to wind 14 Knots, one can kept 100% of the sails surface
- From 14 to 18 Knots, a reefing of 0,9, meaning 81% of the surface, is the best choice
- From 18 to 22 Knots, a reefing of 0,8, meaning 64% of the surface, is the best choice
- From 22 Knots to ...etc, another step of reefing...

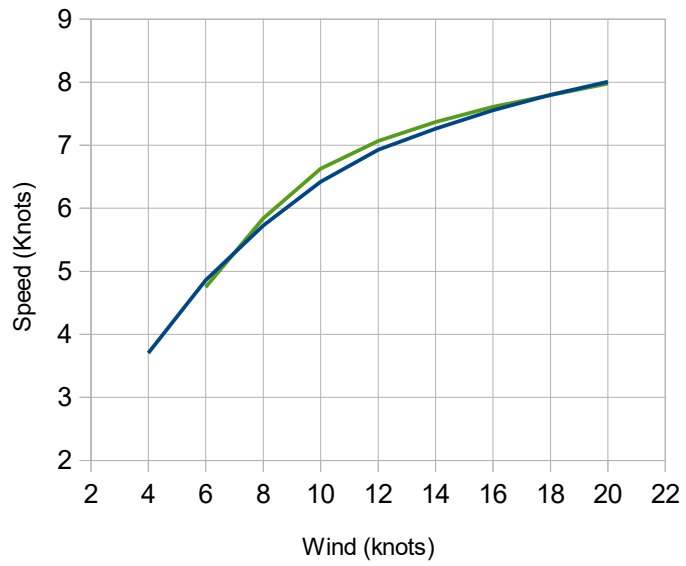
Corbin 39 mk2 49' - Reefing influence on Heel upwind
(with Flat limited to 0,75)

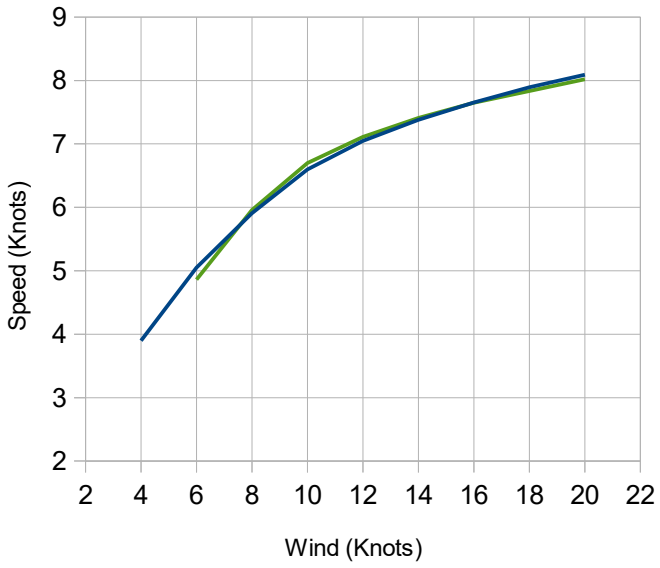


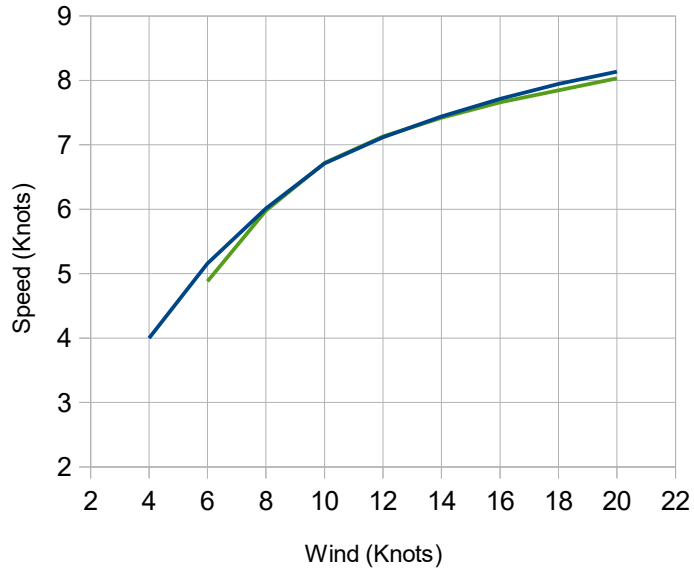
>>> The heel angle figure shows that the change for a reefing showed by the speed figure occurs at approximately the same heel angle, around 22°-24°. It does not worth to sail with a higher heel angle.

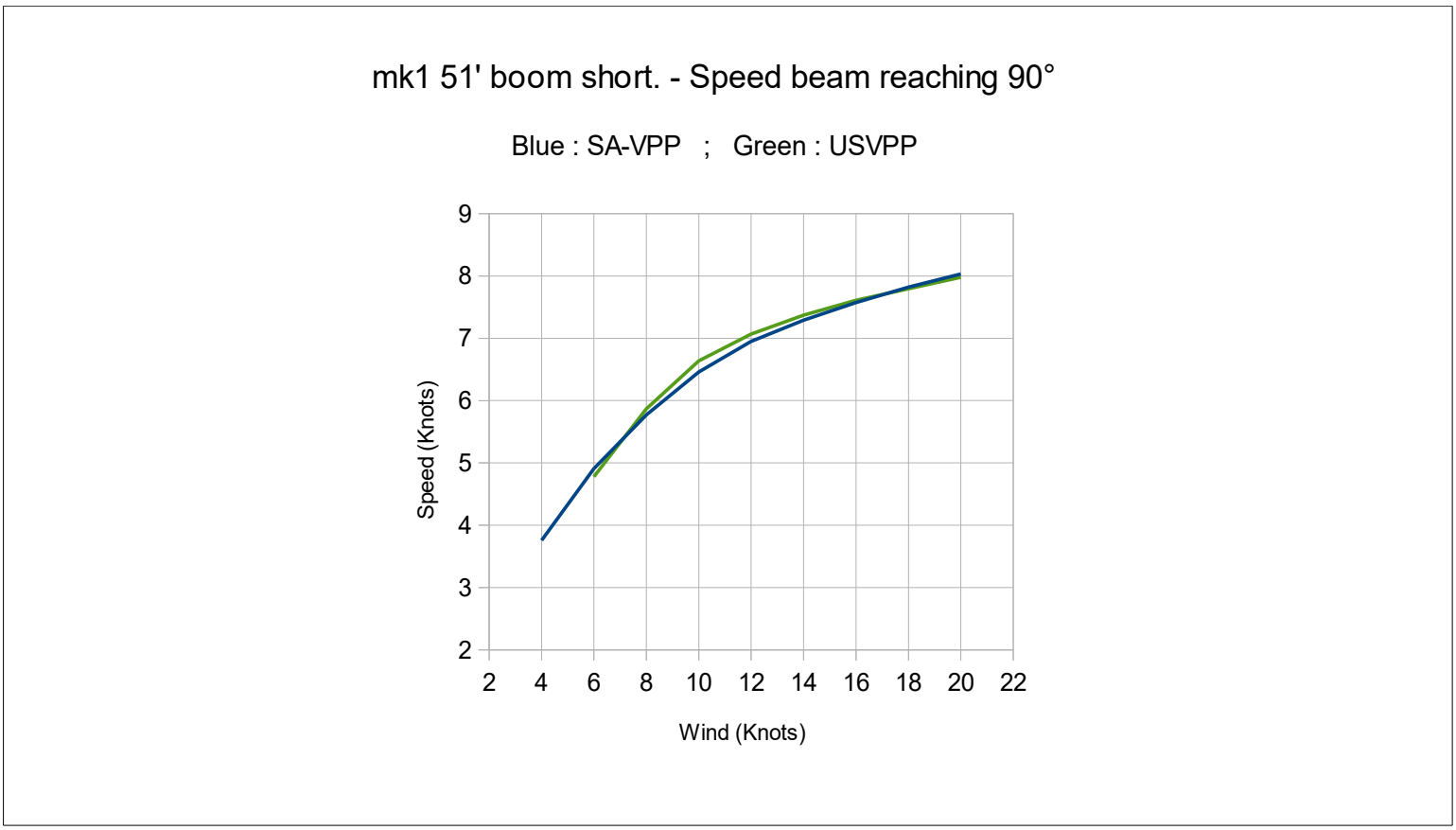
Comparison when beam reaching twa 90°





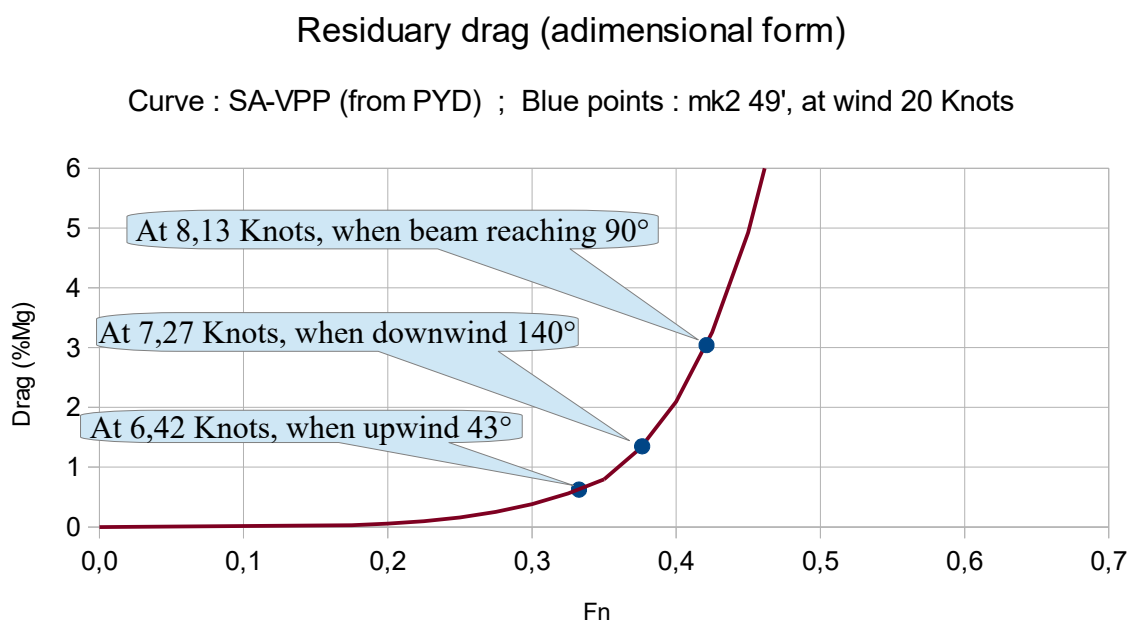




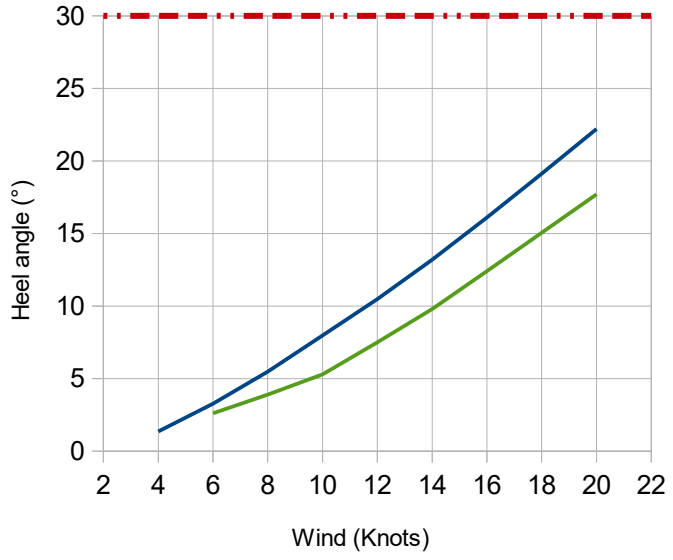


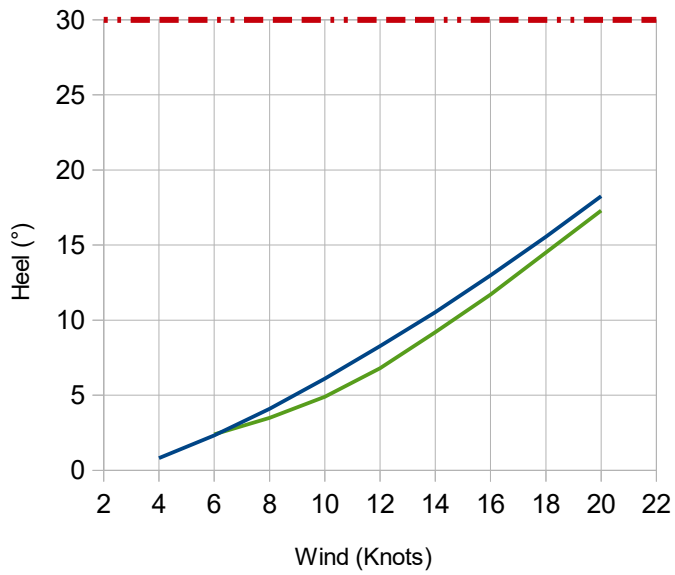
>>> very good concordance between the 2 VPPs

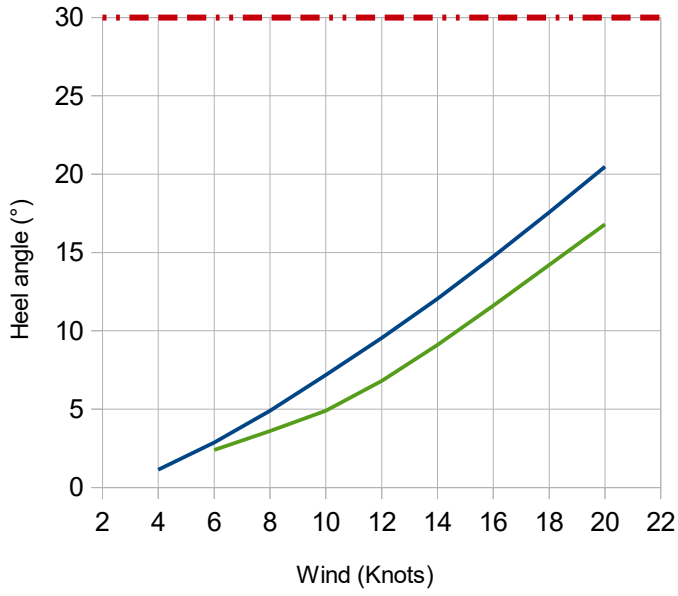
>>> when beam reaching, there is a kind of wall at about boat speed ~ 8 Knots, due to the drag residuary component of which slope becomes very stiff in the Froude 0,36 to 0,43 , i.e. 7 to 8,2 Knots, reaching 75% of the total drag :

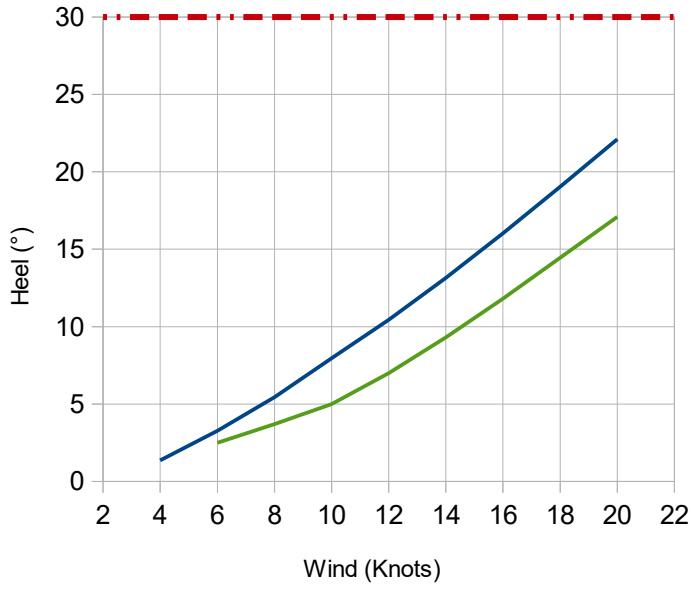


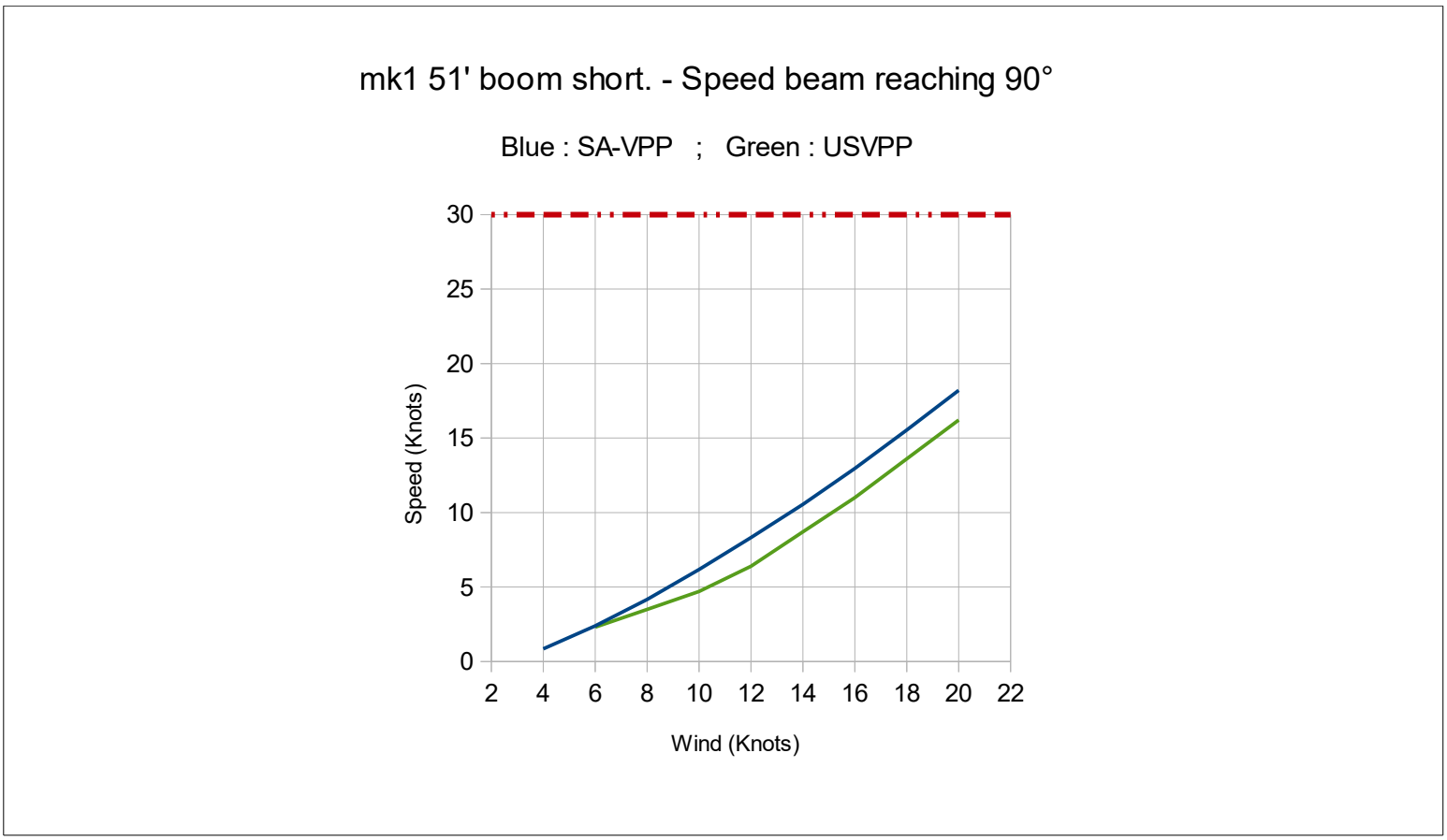
Beam reaching twa 90°, the Heel angles :



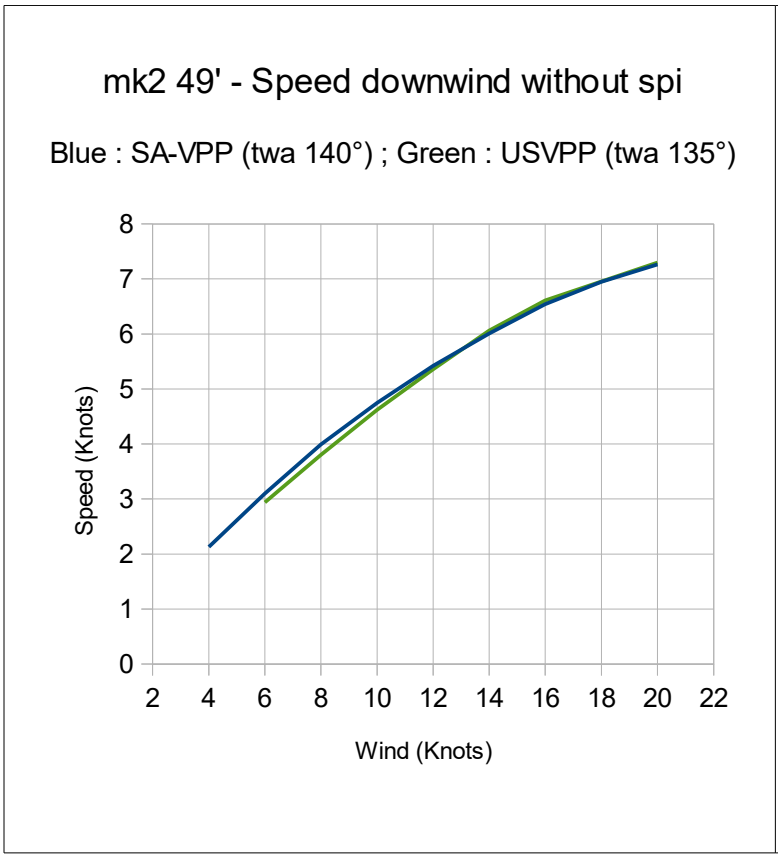


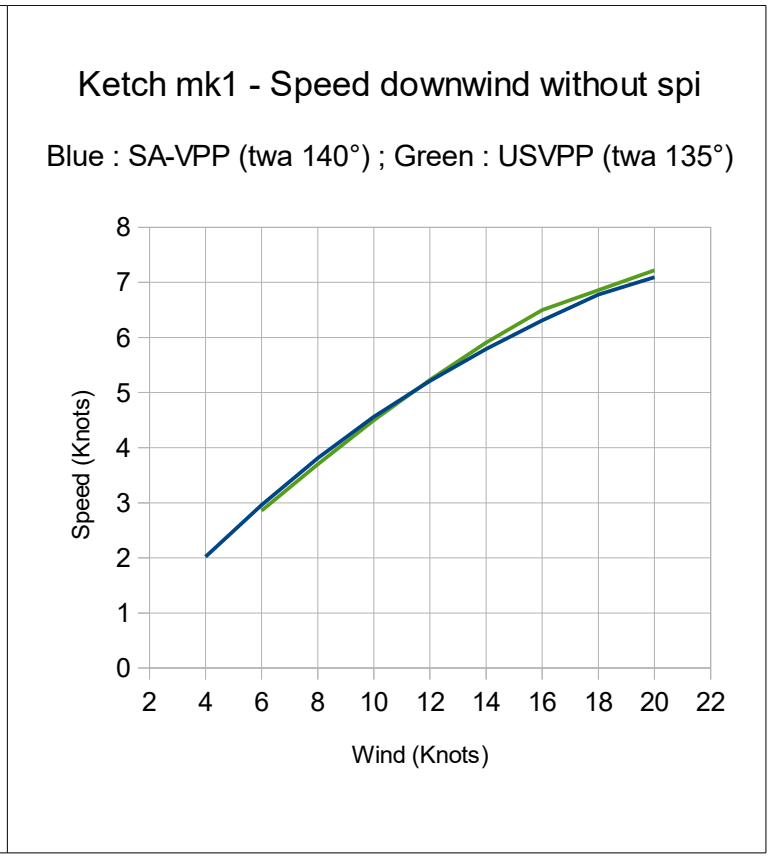






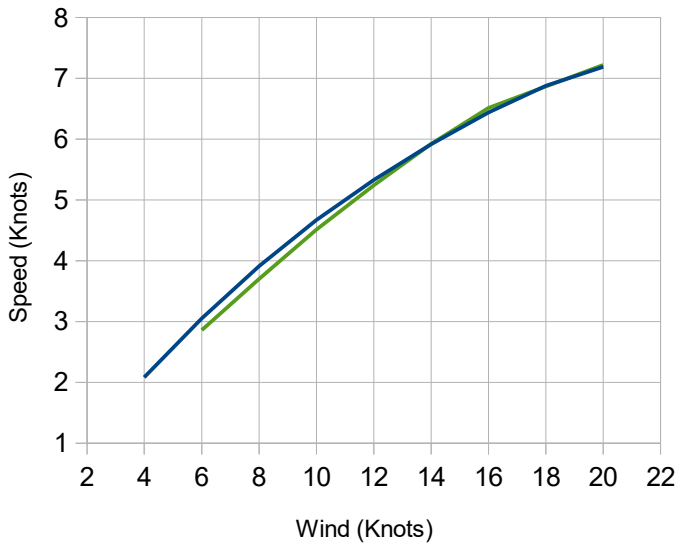
Comparison downwind without spi (SA-VPP : at twa 140° ; USVPP : at twa 135°)





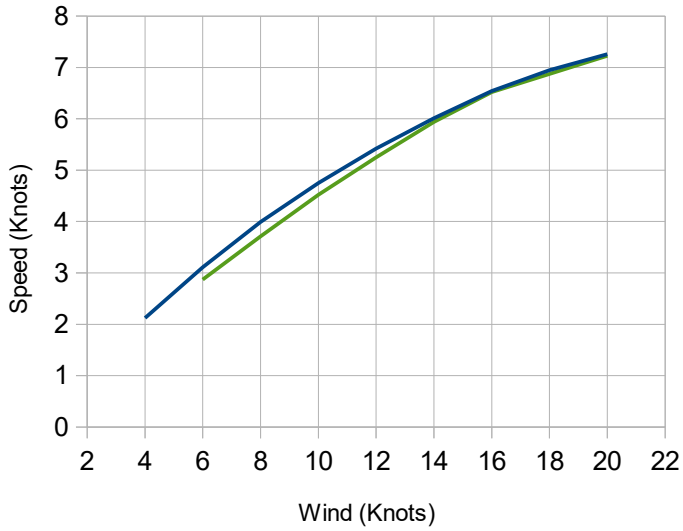
mk1 51' - Speed downwind without spi

Blue : SA-VPP (twa 140°) ; Green : USVPP (twa 135°)



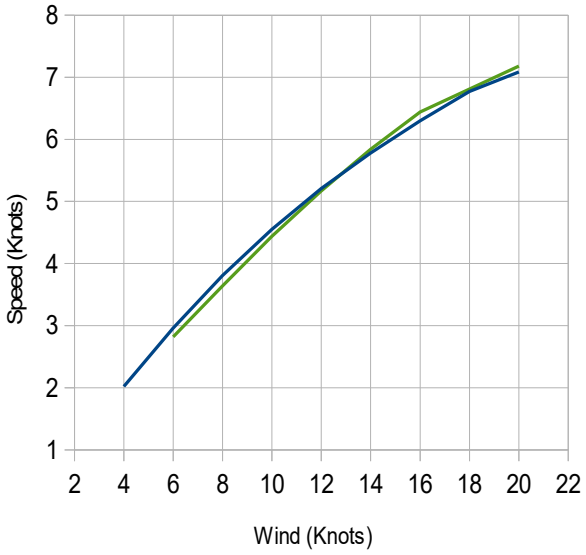
mk1 51' bowsprit - Speed downwind without spi

Blue : SA-VPP (twa 140°) ; Green : USVPP (twa 135°)

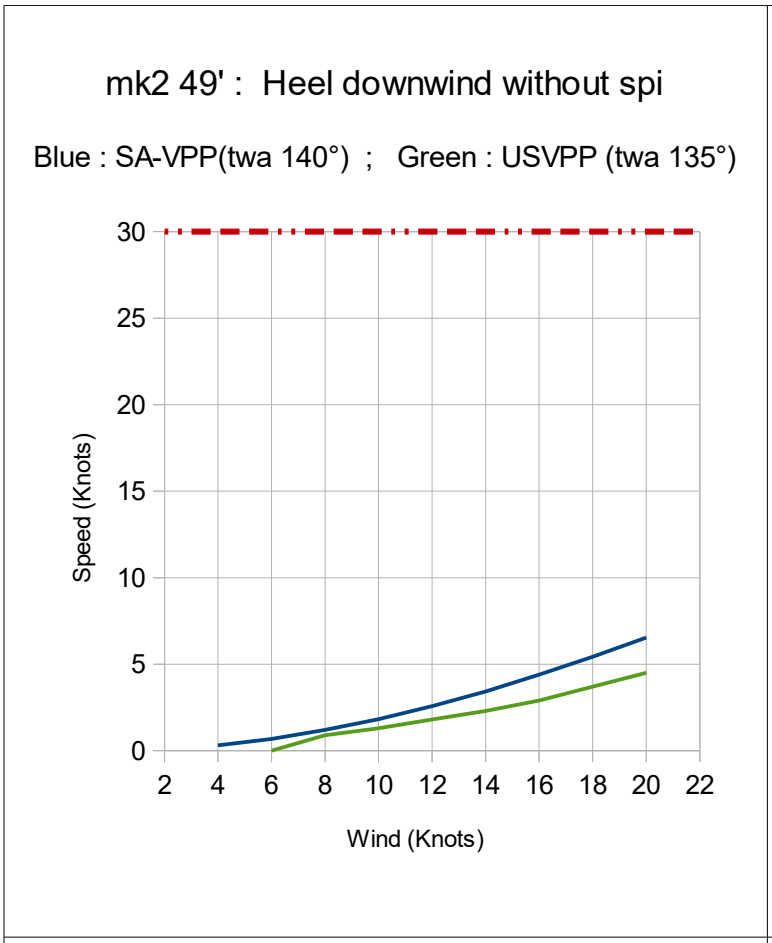


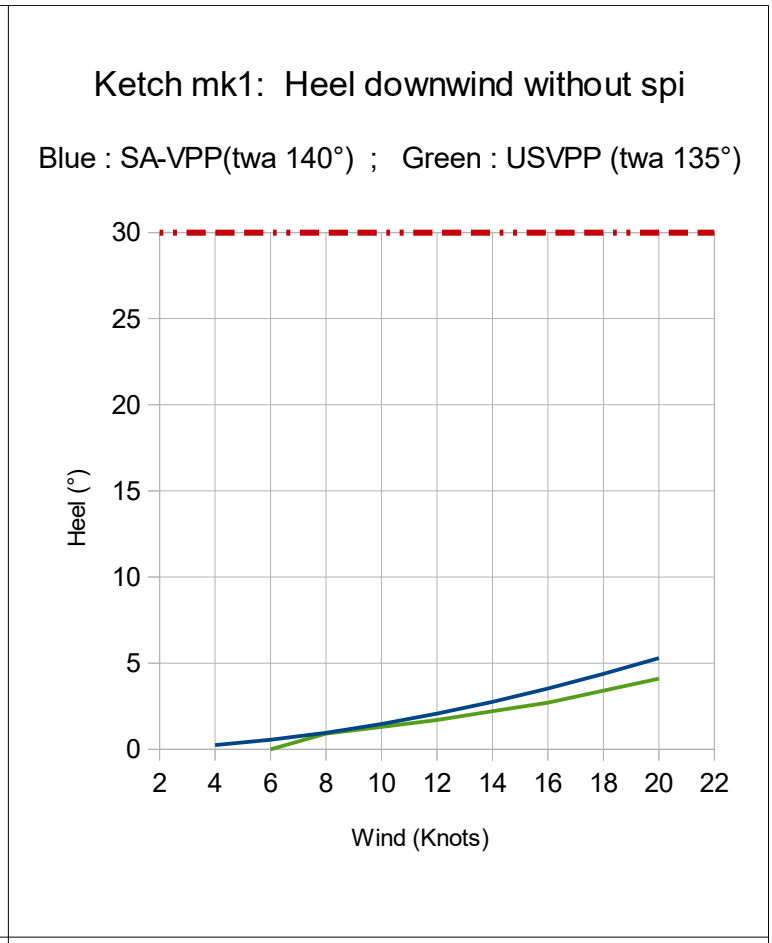
mk1 51' boom shortened - Speed downwind without spi

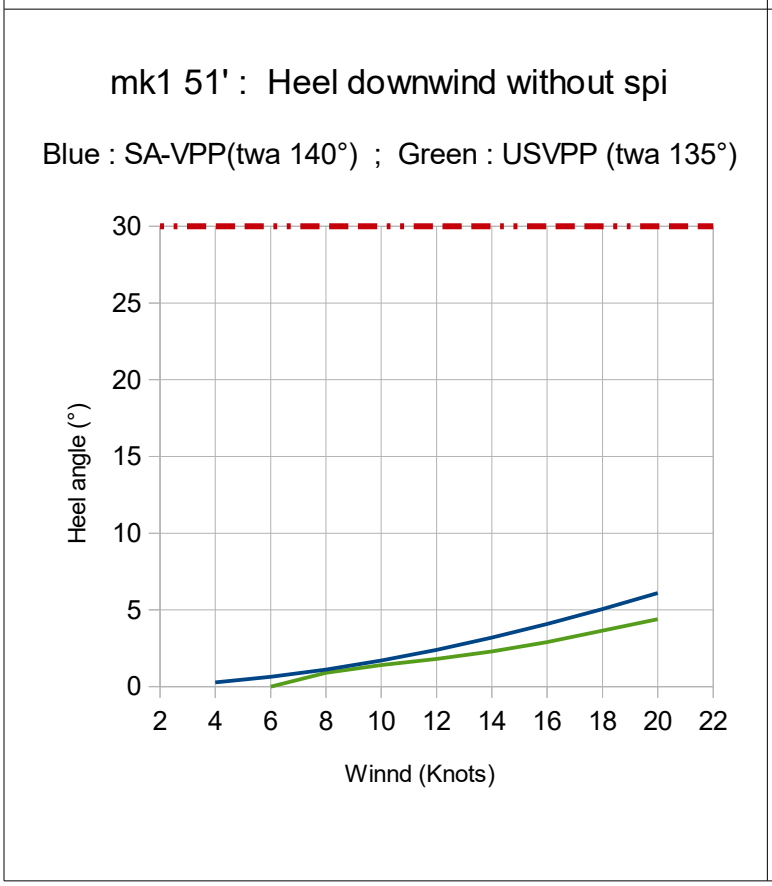
Blue : SA-VPP (twa 140°) ; Green : USVPP (twa 135°)

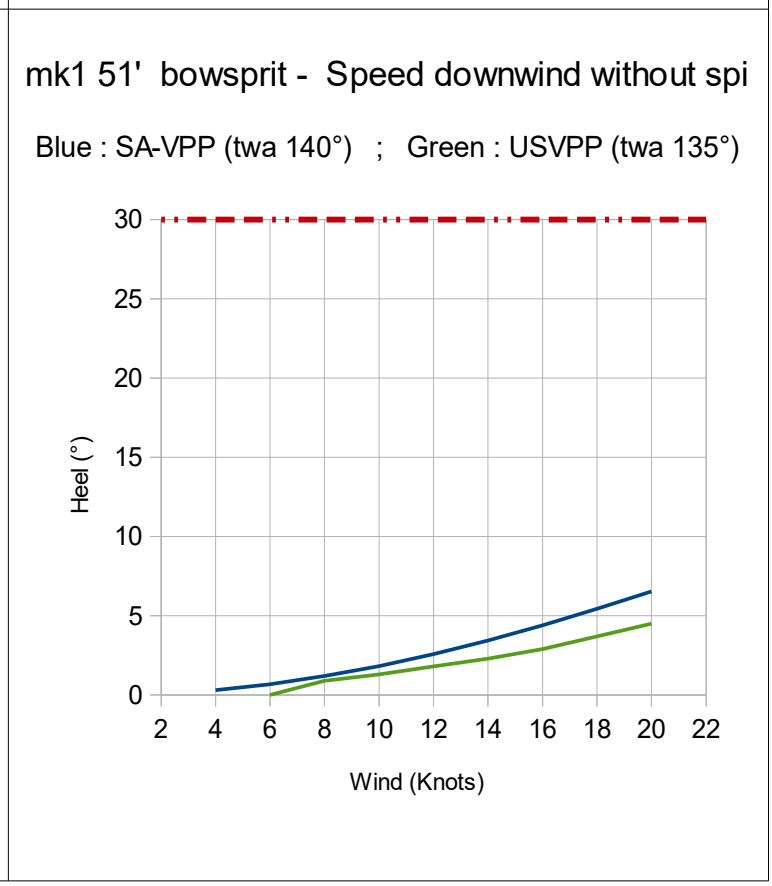


Downwind without spi, the Heel angles



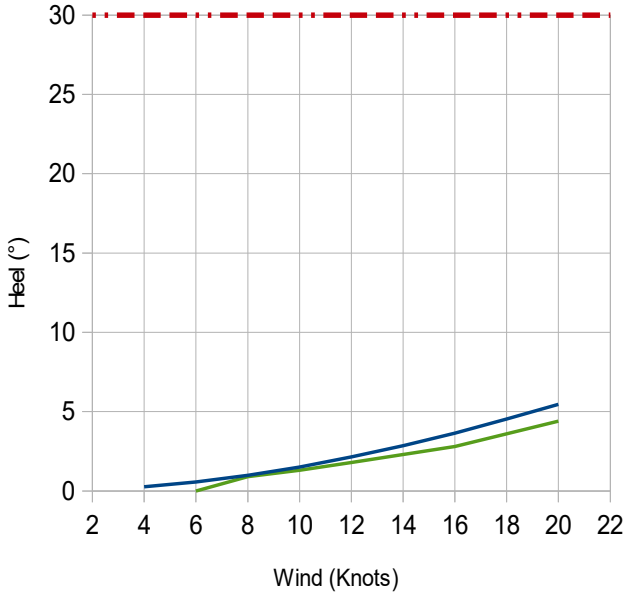






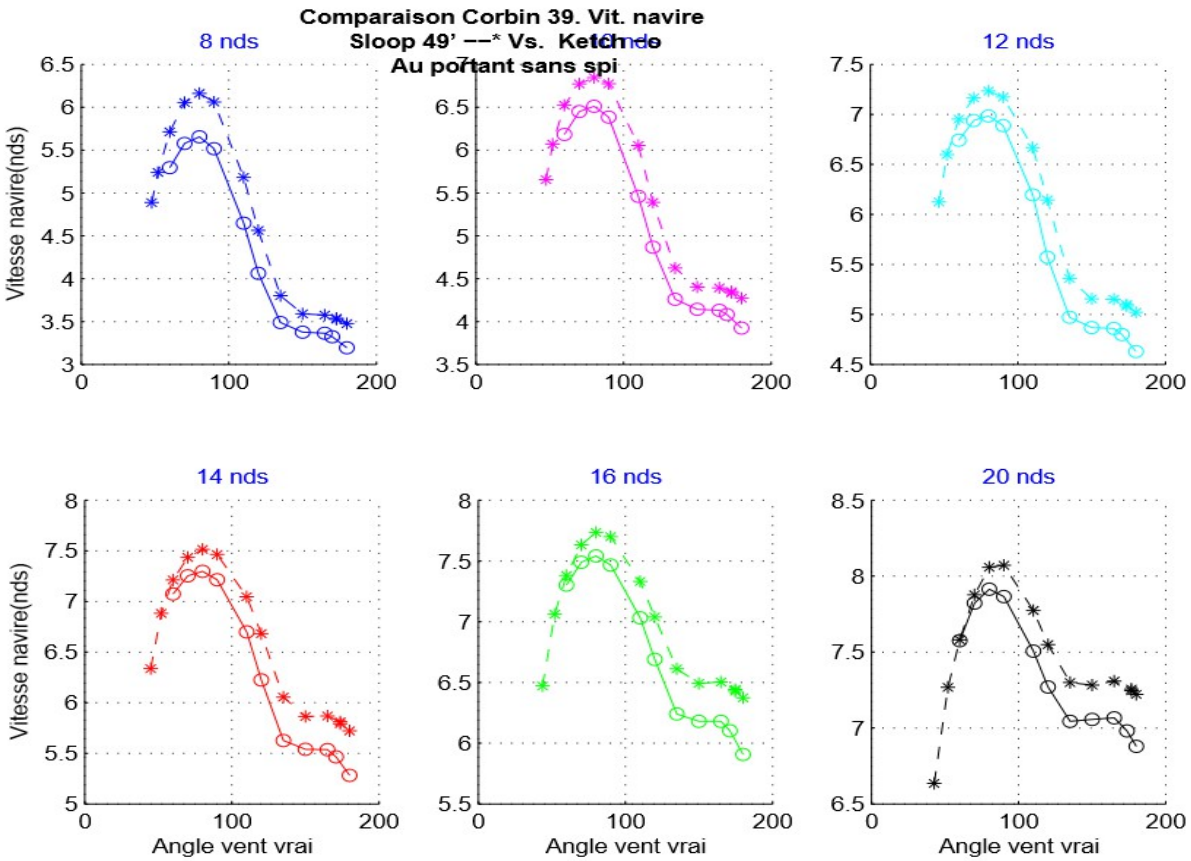
mk1 51' boom shortened - Heel downwind without spi

Blue : SA-VPP (twa 140°) ; Green : USVPP (twa 135°)

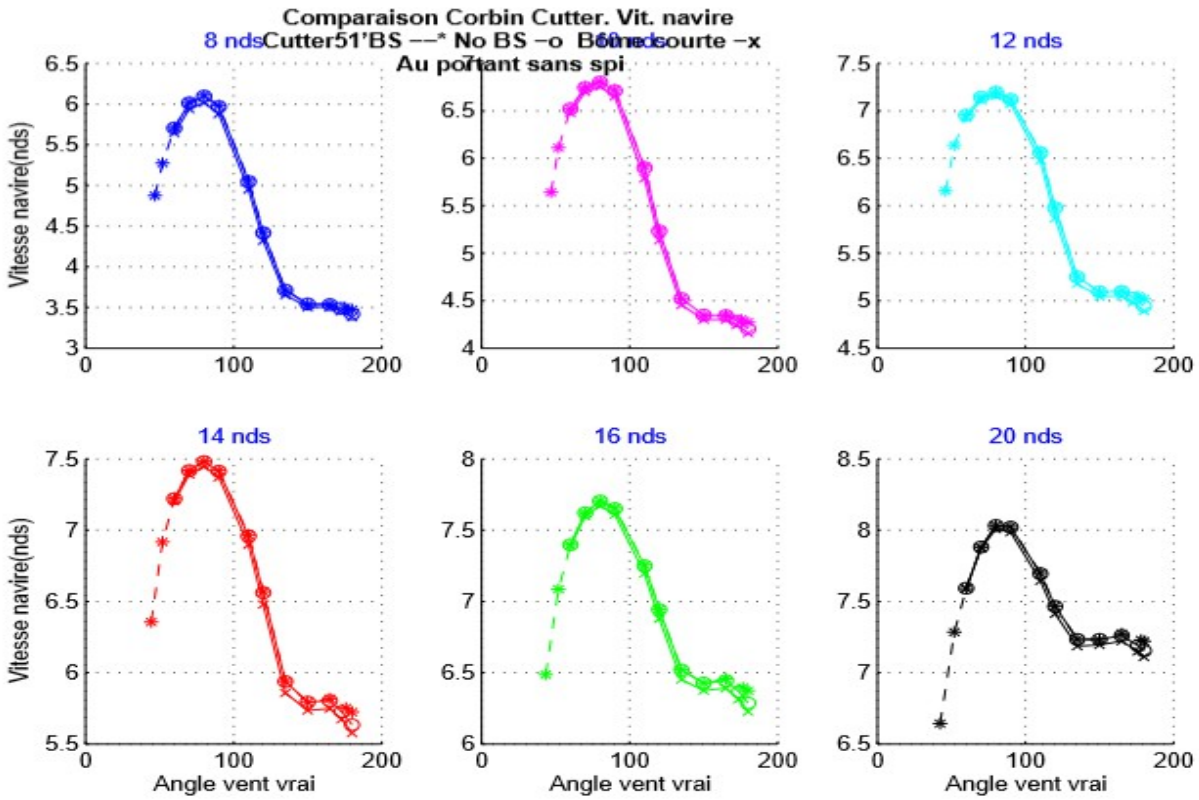


All the speeds obtained with USVPP, in downwind conditions without spi :

For sailplans Sloop mk2 49' (*) and Ketch mk1 (o)



For the 3 mk1 51' sailplans : without (o) and with bowsprit (*), with boom shortened (x)



A synthesis of boat speeds by light wind 8 Knots, moderate wind 14 Knots and breeze wind 20 Knots, as estimated with both SA-VPP and USVPP :

With 8 Knots of wind	**SA-VPP Upwind Twa 47°** Speed (Knots)	**USVPP**	**SA-VPP Beam Twa 90°** Speed (Knots)	**USVPP**	**SA-VPP Downwind Twa 140°** Speed (Knots)	**USVPP Twa 135°**
VPP / Ketch mk1 46'	4,81		5,73		3,81	
VPP / Sloop mk1 51'	4,98	4,86	5,91	5,96	3,91	3,70
VPP / Ketch mk1 46'	4,81	4,67	5,73	5,84	3,81	3,70
VPP / Sloop mk2 49'	4,98	4,89	6,01	6,08	3,99	3,80
VPP / Sloop mk1 46' bowsprit	4,90		5,82		3,87	
VPP / Sloop mk1 51' bowsprit	5,03	4,88	6,01	5,98	3,99	3,71
VPP / Sloop mk1 51' boom shortened	5,02	4,81	5,77	5,87	3,81	3,64

With 14 Knots of wind	**SA-VPP Upwind Twa 44°** Speed (Knots)	**USVPP**	**SA-VPP Beam Twa 90°** Speed (Knots)	**USVPP**	**SA-VPP Downwind Twa 140°** Speed (Knots)	**USVPP Twa 135°**
VPP / Sloop mk1 46'	5,96		7,27		5,77	
VPP / Sloop mk1 51'	6,02	6,36	7,38	7,41	5,92	5,92
VPP / Ketch mk1 46'	5,87	6,21	7,27	7,37	5,79	5,91
VPP / Sloop mk2 49'	5,99	6,34	7,44	7,47	6,01	6,06
VPP / Sloop mk1 46' bowsprit	5,94		7,33		5,86	
VPP / Sloop mk1 51' bowsprit	6,02	6,36	7,44	7,42	6,01	5,94
VPP / Sloop mk1 51' boom shortened	6,04	6,35	7,29	7,37	5,78	5,84

With 20 Knots of wind	**SA-VPP Upwind Twa 43°** Speed (Knots)	**USVPP**	**SA-VPP Beam Twa 90°** Speed (Knots)	**USVPP**	**SA-VPP Downwind Twa 140°** Speed (Knots)	**USVPP**
VPP / Sloop mk1 46'	6,45		8,01		7,08	
VPP / Sloop mk1 51'	6,46	6,64	8,09	8,02	7,19	7,22
VPP / Ketch mk1 46'	6,33	6,53	8,01	7,98	7,10	7,22
VPP / Sloop mk2 49'	6,42	6,64	8,13	8,07	7,27	7,30
VPP / Sloop mk1 46' bowsprit	6,43		8,06		7,15	
VPP / Sloop mk1 51' bowsprit	6,44	6,64	8,14	8,03	7,26	7,23
VPP / Sloop mk1 51' boom shortened	6,48	6,64	8,03	8,03	7,09	7,18

Annex 1 : input data for the VPPs

D : 14000 kg — corresponding to a hull sinkage of 12,9 cm

Lwl : 10,05 m — the Lwl with a sinkage of 12,9 cm and trim 0°

Bwl : 3,52 m — the value of the linesplan at Z 12,9 cm, also an average value between Gene-Hull and Multisurf ones

Draft : 1,81 m — = 1,676 + sinkage 0,129

Draft hull : 0,89 m — = 0,762 + 0,129

Bmax Hull : 3,71 m

Sw hull alone : 25,93 m2 — inc. the 12,9 cm sinkage, not inc. the keel connection, it is the Multisurf value when D 14000 kg and after substraction of 7,95 m2 (the Sw of the keel) and of 2,44 m2 (the Sw of the skeg-rudder)

Waterplane aera : 25,02 m2 — (use only for the residuary drag estimation when Froude > 0,475)

Cp hull alone : 0,631 — The Cp hull increases significantly with the sinkage, from 0,575 (at Z0) to 0,631 (at Z 12,9 cm)

LCB : 4,505 m = 47,0 % Lwl — (considering the Lwl above, 10,05 m from X -0,22 m to X 9,83m)

Sailplans and correspondance for the SA-VPP

Rules adopted within SA-VPP to input the sails surface and geometry as an equivalent wing :

Sailplan option and real sails	Data for the VPP		
	SA triangles	Z CE triangles / H0	Z Mainsail top / H0
Sloop mk1 46' shortmast Genoa : 49,6 m2 (143%) Main : 34,2 m2	**68,9 m2**	**6,61 m**	**15,46 m**
Sloop mk1 51' tallmast Genoa : 55,0 m2 (143%) Main : 36,5 m2	**75,0 m2**	**7,10 m**	**16,98 m**
Ketch mk1 Genoa : 41,4 m2 (143%) Main : 30,3 m2 Mizzen : 12,3 m2	**Upwind** **68,65 m2** **Downwind** **69,90 m2**	**6,65 m**	**15,46 m**
Sloop mk2 49' bowsprit Genoa : 60,4 m2 (157%) Main : 40,6 m2	**80,70 m2**	**6,99 m**	**16,48 m**

Sloop mk1 46' bowsprit Genoa : 49,6 m2 (122%) Main : 34,2 m2	**73,7 m2**	**6,57 m**	**15,46 m**
Sloop mk1 51' bowsprit Genoa : 55,0 m2 (122%) Main : 36,5 m2	**80,3 m2**	**7,06 m**	**16,98 m**
Sloop mk1 51' boom shortened by 36'' Genoa : 55,0 m2 (143%) Main : 29,3 m2	**68,6 m2**	**7,05 m**	**16,98 m**

Parasite drag coefficient for the rig :

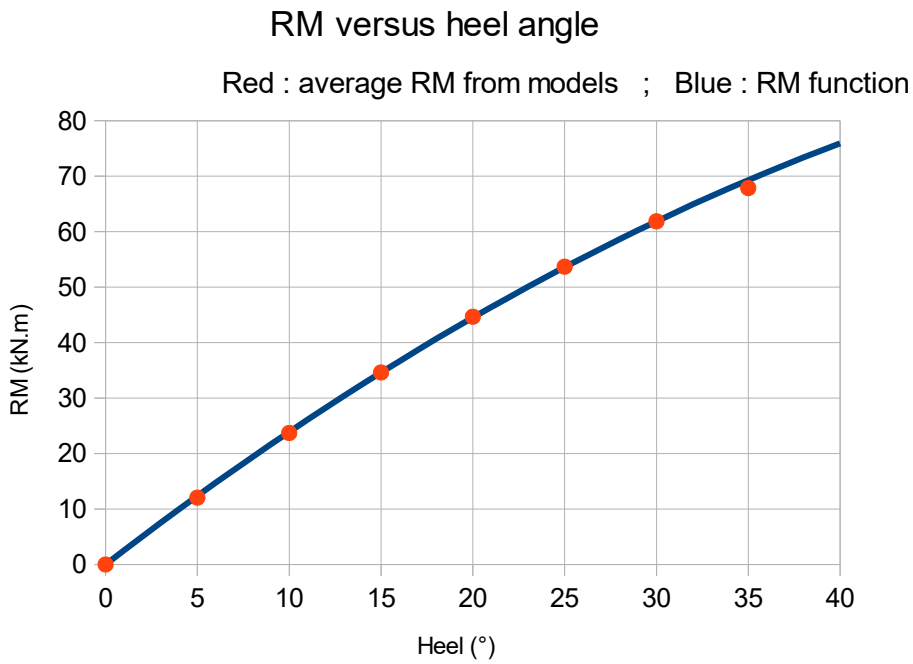
Sloop : Cd0 = 0,02 ; Gréement ketch : Cd0 = 0,0348 (due to 2 masts)

Keel volume : 0,95902 m3
Keel Sw : 6,95 m2
Keel chord : 4,65 m (use for the Reynolds, in the friction drag computation)

Skeg-rudder volume : 0,09403 m3
Skeg-rudder Sw : 2,44 m2
Skeg-rudder chord : 1,02 m (use for the Reynolds, in the friction drag computation)

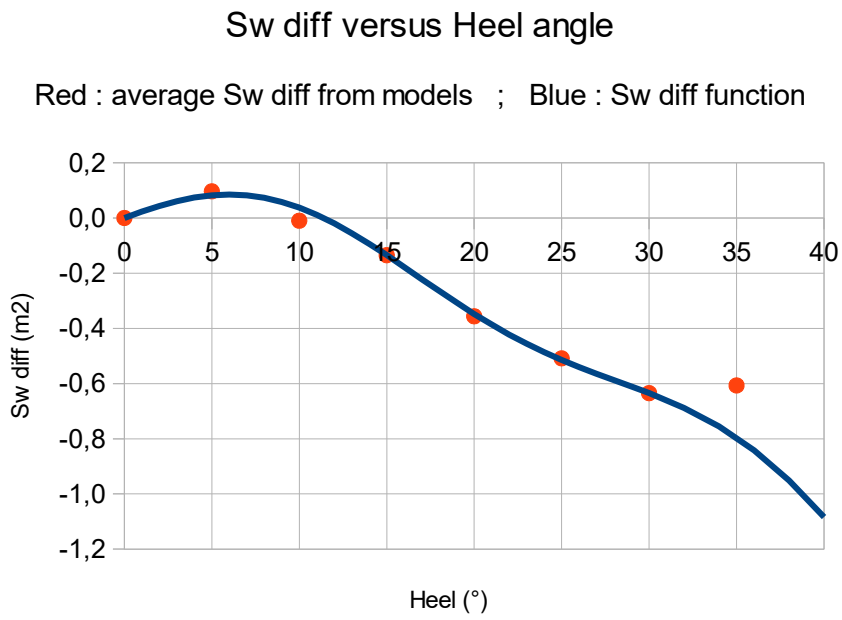
The RM function : based on the average values of the 3 models (Gene-Hull, Multisurf, Delfship) up to 35°

Heel (°)	Average RM (kN.m)
0	0,00
5	12,05
10	23,71
15	34,62
20	44,67
25	53,69
30	61,86
35	67,87



The Sw diff function : based on the average values of the 2 models (Gene-Hull, Multisurf) up to 35°

Heel (°)	Average Sw diff (m2)
0	0,000
5	0,097
10	-0,010
15	-0,135
20	-0,356
25	-0,509
30	-0,635
35	-0,607



Annex 2 - The owners answers to the enquiry

I have proposed your upwind speeds to the group:

Wind force 2 (4 to 6 Knts) >> Speed 3,9 to 4,6 Knots ?

Wind force 3 (7 to 10 Knts) >> Speed 5,3 to 5,9 Knots ?

Wind force 4 (11 to 16 Knts) >> Speed 6,1 to 6,5 Knots ?

Wind force 5 (17 Knts to 21 Knts) >> Speed 6,6 to 6,7 Knots ? (with a necessary sail reduction to 80% at Wind 18 Knots)

1. Response for #97, “Grace” which is a mk1 double-spreader tallmast with no bowsprit : The 3 blade folding Maxprop gives me +.5 knots over my previous fixed three blades, under sail. My numbers are very close to the above at force 4 and above but a little slower at the lower winds. My foresail is only a 110 high Yankee cut roller hanked 30 year old- my main is new with three reef points - first reef is used if there will be anything above force 3 that day. Grace’s main is way overpowered but manageable once you understand her. The folding prop (Maxprop) was a very helpful improvement.

2. Response for #61, “Cosmic Debris”, which is a mk1 double-spreader tallmast with a bowsprit : I have actually never had a working knot meter on my boat so it's difficult to say. Relying only on SOG and and sailing in reasonably calm sea states I would those speeds are probably fairly accurate. We have reached hull speed in 15kn wind while beating but favourable current would likely be a factor.

3. Response for #143, “Sputnik III”, which is a mk2 double-spreader tallmast with a bowsprit : That's more or less ok, but depending of the sea state. With the short waves against my course I needed to use genoa + jib + mainsail and I was able to make about 80% of those values. Especially with wind force 5 or more the effect of the short sea is to slow the boat when sailing upwind.

4. Response for #107, ”Full Circle, which is a mk1 shortmast single spreader with no bowsprit. “Full Circle” would have speeds on the lower ends of those ranges. Our boat has the Genoa track on the cap rail which results in less than ideal sheeting angle. In an ideal world they would be mounted along the pilot house on side deck.

5. Response for #073, “Jakatar”, mk1, 50’ shortmast single spreader, no bowsprit

   Main: 34 m2

   High cut genoa: 48 m2

   Boomed staysail: 12 m2

   I worked out the speeds to the best of my memory. I found that the [initially suggested speeds are] somewhat optimistic at low wind speeds; can’t imagine doing 3.9 knots in 4 knots of wind in any wind direction. Corbins need a bit of wind on a close reach.

   Note: I’ve done 8.5+ knots but that’s in extreme conditions (never on a close reach), maybe also helped by waves.

   Close Reach

   Wind force 2 (4 to 6 Knts) >> Speed 2 to 3 Knots

   Wind force 3 (7 to 10 Knts) >> Speed 3.5 to 4.5 Knots

   Wind force 4 (11 to 16 Knts) >> Speed 5 to 5.5 Knots

   Wind force 5 (17 Knts to 21 Knts) >> Speed 6 to 7 Knots

   Beam Reach

   Wind force 2 (4 to 6 Knts) >> Speed 2 to 3 Knots

   Wind force 3 (7 to 10 Knts) >> Speed 3.5 to 5 Knots

   Wind force 4 (11 to 16 Knts) >> Speed 5.5 to 6.5 Knots

   Wind force 5 (17 Knts to 21 Knts) >> Speed 6.5 to 7.5 Knots

   Broad Reach

   Wind force 2 (4 to 6 Knts) >> Speed 1 to 2.5 Knots

   Wind force 3 (7 to 10 Knts) >> Speed 3 to 4.5 Knots

   Wind force 4 (11 to 16 Knts) >> Speed 5 to 6 Knots

   Wind force 5 (17 Knts to 21 Knts) >> Speed 6.5 to 7.5 Knots

6. Response for #xxx, “Abenaki”, mk1, 50’ shortmast single spreader, no bowsprit : The proposed numbers sound about right. They like more wind to get them going. I have had 8knts waterspeed with 20kts of wind, close hauled. More typically 7kts. I have a Bruntons folding prop which I think is worth 0.8 kts. Beam reach and running downwind in 15kts for 6kts waterspeed average.