SA-VPP Power Catamaran 1.1_User Guide

Jean-François Masset – July 2021 contact : jfcmasset@outlook.fr

Version 1.1 : proposes a better estimation of the drag in the low Froude range 0 to 0,4 thanks to the use of the Holtrop-Mennen formulations for the residuary drag in that range (and also valid for Lw/Bw > 7) and for the drag of the immersed rear transoms if any.

SA-VPP Power Catamaran 1.1 (Velocity Prediction Program) makes possible the prediction of the catamaran drag and power to install for speeds in the Froude range 0 to 1. Conditions of validity are :

- Length Beam ratio Lw/Bw > 7
- Length Displacement ratio Lw/Dc^(1/3) > 6,5
  (Length, Beam, Displacement here considered for one hull)
- Space Length S/Lw ratio 0,3 to 0,5

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

User guide

The spreasheet application includes 2 sheets :

- SA-VPP
- Data storage , where can be stored the various set of input data

SA-VPP : includes an User space (input & outputs) followed by an Administrator space (from line 74) where all the computations are carried out. The User space includes :

The data to input

Example 3	Lwl (m)	Bwl (m)	Tc (m)	i (°)	Sw (m2)	Disp. (m3)	Cp	At (m2)	LCB (%Lw)
Each Hull >>	15,00	1,60	0,77	9,44	25,40	7,70072	0,565	0,061	45,95
	Hulls axis space S (m)		Saero (m2)	Cx aero	Propulsion efficiency		Cms	Cwp	
Cata >>	6,10		23	0,40	0,54		0,73	0,73	

For each hull :

Lwl (m) : lenght of waterline

Bwl (m) : beam of waterline

Tc (m) : hull body draft

i (°) : half entry angle of the waterline at bow (neglecting the local rounded shape at the stem)

Sw (m2) : wetted area of one hull

Disp. (m3) : displacement of one hull (i.e. half displacement of the catamaran)

Cp : hull prismatic coefficient

LCB (%) : Longitudinal center of buoyancy, in % of Lwl from aft perpendicular

At (m2) : immersed part of the transom area at zero speed

Cms : midship section coefficient (section /Lw Bw)

Cwp : waterplane area coefficient (Sf / Lw Bw)

For the catamaran as a whole :

S (m) : transversal space between the 2 hulls axis

Saero (m2) : the frontal section

Cx aero : The Cx to take into account for the wind drag comptutation (to estimate due to the overall shape of the superstructure)

Propulsion efficviency : to estimate with the one for the propeller and the one of the mechanical transmission. Example : 0,54 = 0,6 (propeller) x 0,9 (mechaniccal transmission)

On the right side of the input data is a check of the ratios / necessary conditions :

	Conditions :
> Lw/Bw	
9,38	> 7
>Lw/Dc^(1/3)	
7,60	> 6,5
> S/Lw	
0,41	0,3 to 0,5

Output data

, include the main figures and 3 curves :

Ship			Hulls frictional drag Df			Hull residuary drag Dr									Transom drag	Aero drag	D total	> Power net		Power
Vb	Vb	½ Rho Vb^2	Re hull	Cf hull	Df	Fn	Holtrop Rw-A	Formule 1	Formule 2	Formule 3	> Formule	Dr/mg (%)	K interhull	Dr	Dtr	Daero	Dtot	EHP	EHP	to install
(Knots)	(m/s)				(kN)		%	Fn < 0,4	0,4< Fn< 0,6	Fn > 0,6	all Fn			(kN)	(kN)	(kN)	(kN)	(kW)	(hp)	(hp)
0,0	0,000	0,0			0,000	0,000	0,000	0,000	-12,329	0,699	0,000	0,000	0,31	0,000	0,000	0,000	0,000	0,00	0,00	0,0
0,8	0,404	83,8	4,25E+006	0,0035	0,015	0,033	0,000	0,001	-10,636	0,875	0,001	0,000	0,31	0,000	0,002	0,001	0,018	0,01	0,01	0,0
1,6	0,809	335,2	8,49E+006	0,0031	0,053	0,067	0,000	0,006	-9,037	1,051	0,006	0,000	0,31	0,000	0,006	0,004	0,062	0,05	0,07	0,1
2,4	1,213	754,1	1,27E+007	0,0029	0,110	0,100	0,000	0,022	-7,531	1,228	0,022	0,000	0,31	0,000	0,012	0,008	0,130	0,16	0,21	0,4
3,1	1,617	1340,7	1,70E+007	0,0027	0,187	0,133	0,001	0,056	-6,118	1,404	0,056	0,001	0,31	0,001	0,017	0,015	0,219	0,35	0,48	0,9
3,9	2,022	2094,8	2,12E+007	0,0026	0,281	0,167	0,004	0,113	-4,798	1,581	0,113	0,004	0,31	0,009	0,020	0,023	0,333	0,67	0,90	1,7
4,7	2,426	3016,6	2,55E+007	0,0026	0,393	0,200	0,018	0,202	-3,572	1,757	0,202	0,018	0,31	0,037	0,019	0,033	0,483	1,17	1,57	2,9
5,5	2,830	4105,9	2,97E+007	0,0025	0,522	0,233	0,052	0,330	-2,438	1,934	0,330	0,052	0,31	0,106	0,014	0,045	0,687	1,95	2,61	4,8
6,3	3,235	5362,8	3,40E+007	0,0025	0,668	0,267	0,111	0,505	-1,398	2,110	0,505	0,155	0,31	0,315	0,002	0,059	1,044	3,38	4,53	8,4
7,1	3,639	6787,3	3,82E+007	0,0024	0,830	0,300	0,188	0,735	-0,452	2,286	0,735	0,370	0,32	0,755	0,000	0,075	1,660	6,04	8,10	15,0
7,9	4,044	8379,4	4,25E+007	0,0024	1,008	0,333	0,337	1,029	0,402	2,463	1,029	0,721	0,32	1,474	0,000	0,092	2,575	10,41	13,96	25,9
8,6	4,448	10139,0	4,67E+007	0,0023	1,202	0,367	0,622	1,394	1,162	2,639	1,394	1,222	0,32	2,502	0,000	0,111	3,816	16,97	22,76	42,1
9,4	4,852	12066,3	5,09E+007	0,0023	1,411	0,400	1,025	1,839	1,829	2,816	1,829	1,829	0,32	3,750	0,000	0,133	5,294	25,69	34,44	63,8
10,4	5,372	14790,5	5,64E+007	0,0023	1,704	0,443		2,543	2,550	3,042	2,550	2,550	0,32	5,221	0,000	0,163	7,087	38,07	51,05	94,5
11,5	5,892	17791,6	6,19E+007	0,0022	2,021	0,486		3,412	3,117	3,269	3,117	3,117	0,31	6,304	0,000	0,196	8,521	50,21	67,33	124,7
12,5	6,412	21069,9	6,73E+007	0,0022	2,363	0,529		4,467	3,529	3,496	3,529	3,529	0,28	6,997	0,000	0,232	9,592	61,50	82,48	152,7
13,5	6,932	24625,1	7,28E+007	0,0022	2,730	0,571		5,726	3,787	3,723	3,787	3,787	0,25	7,351	0,000	0,271	10,352	71,76	96,23	178,2
14,5	7,452	28457,4	7,82E+007	0,0022	3,122	0,614		7,210	3,892	3,950	3,950	3,950	0,23	7,536	0,000	0,313	10,970	81,75	109,62	203,0
15,5	7,971	32566,7	8,37E+007	0,0021	3,537	0,657		8,937	3,842	4,177	4,177	4,177	0,22	7,881	0,000	0,358	11,776	93,87	125,89	233,1
16,5	8,491	36953,0	8,92E+007	0,0021	3,977	0,700		10,930	3,638	4,403	4,403	4,403	0,21	8,261	0,000	0,406	12,644	107,36	143,97	266,6
17,5	9,011	41616,4	9,46E+007	0,0021	4,440	0,743		13,207	3,280	4,630	4,630	4,630	0,21	8,664	0,000	0,458	13,561	122,21	163,88	303,5
18,5	9,531	46556,8	1,00E+008	0,0021	4,927	0,786		15,791	2,768	4,857	4,857	4,857	0,21	9,080	0,000	0,512	14,518	138,38	185,56	343,6
19,5	10,051	51774,3	1,06E+008	0,0021	5,437	0,829		18,701	2,102	5,084	5,084	5,084	0,21	9,501	0,000	0,569	15,507	155,86	209,01	387,1
20,5	10,571	57268,8	1,11E+008	0,0021	5,970	0,871		21,960	1,281	5,311	5,311	5,311	0,21	9,924	0,000	0,630	16,524	174,68	234,24	433,8
21,6	11,091	63040,3	1,16E+008	0,0020	6,527	0,914		25,588	0,307	5,537	5,537	5,537	0,21	10,348	0,000	0,693	17,568	194,84	261,29	483,9
22,6	11,611	69088,8	1,22E+008	0,0020	7,107	0,957		29,608	-0,822	5,764	5,764	5,764	0,21	10,772	0,000	0,760	18,638	216,40	290,19	537,4
23,6	12,131	75414,4	1,27E+008	0,0020	7,709	1,000		34,041	-2,104	5,991	5,991	5,991	0,21	11,196	0,000	0,829	19,734	239,38	321,01	594,5

Df is the frictional drag

Dr is the residuary drag

, where K is the interhulls factor due to waves interference :

Dr cata = (1+K) (Dr of the 2 hulls)

Dtr is the rear transoms drag

Daero is the aerodynamical drag

Dtot is the total drag

EHP : net propulsion power (= drag x speed)

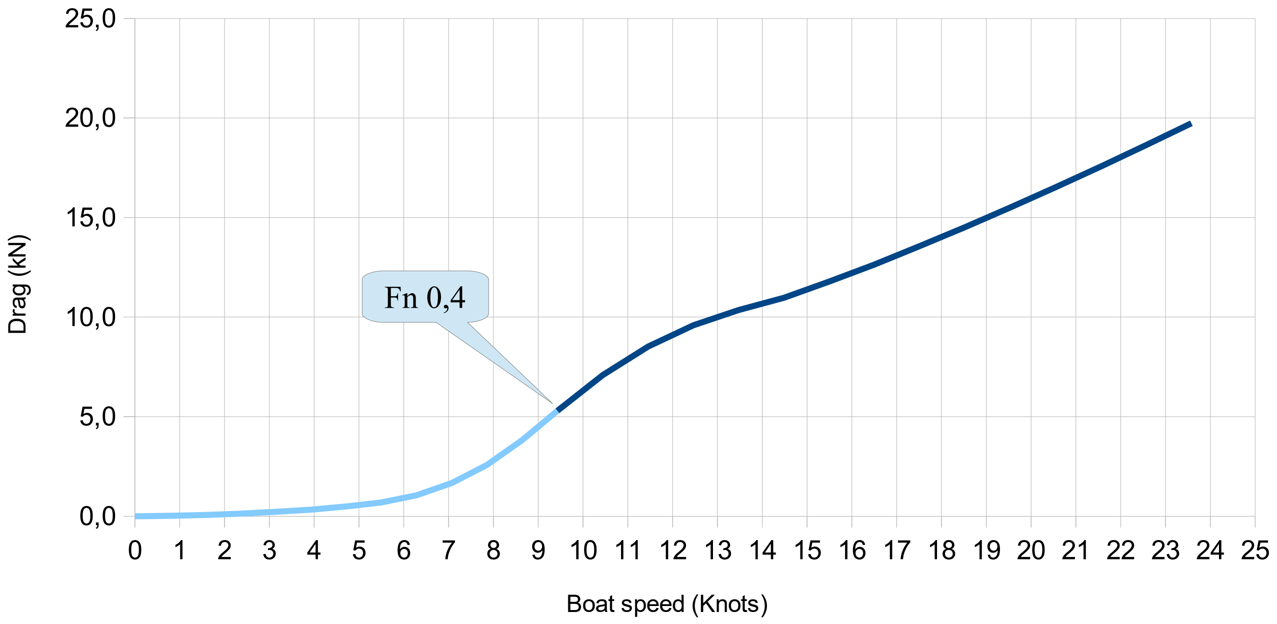
Power to install : taken into account the propulsion efficiency

Example of figures :

….. / ……

SA-VPP Power Catamaran - Drag

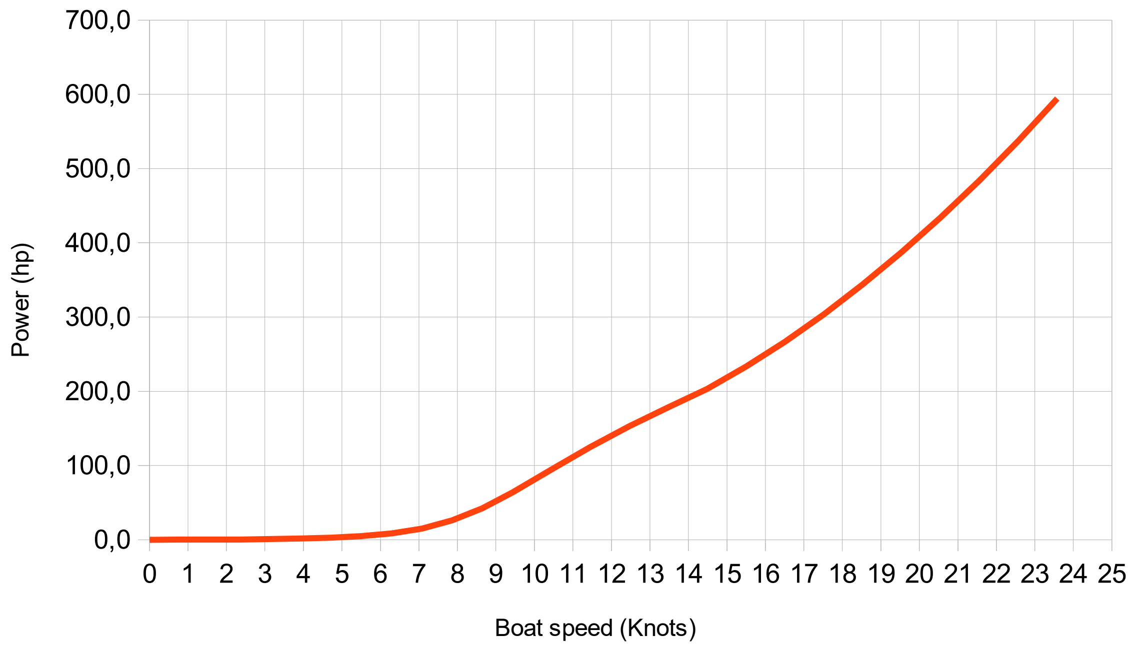
(calm water, no wind)

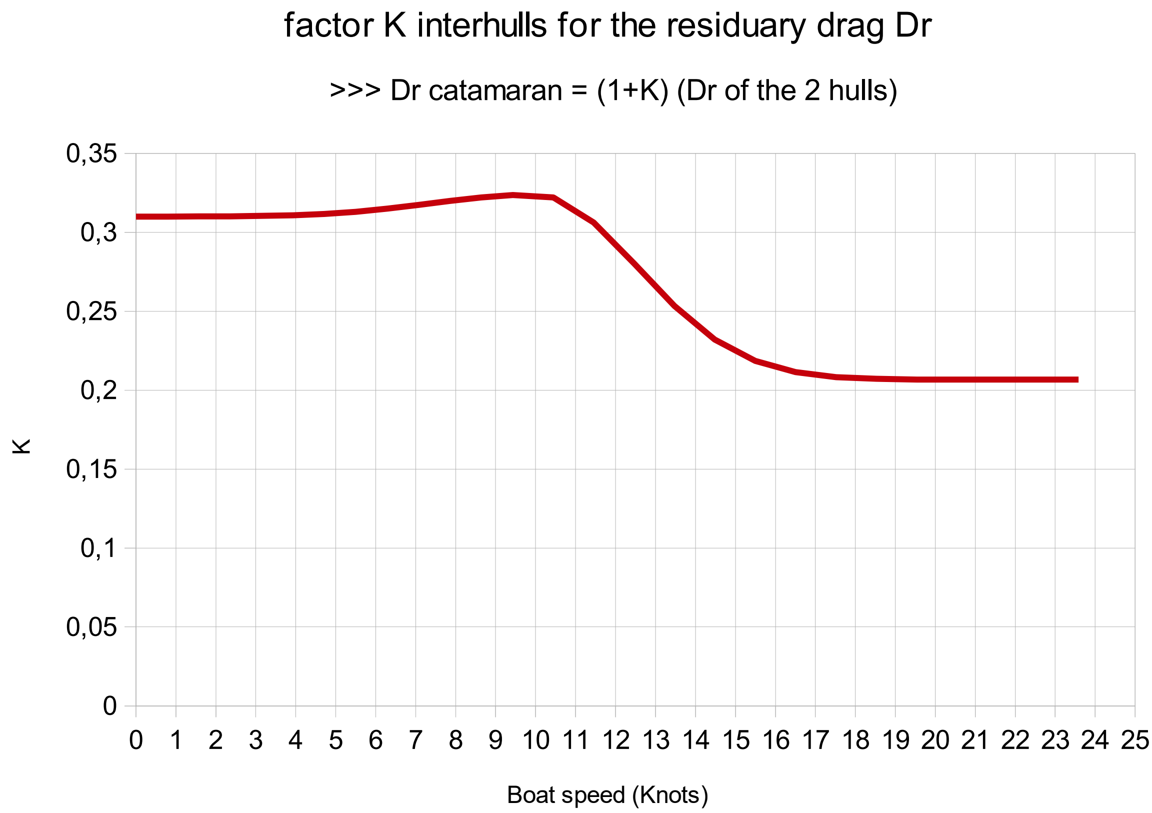


>>> here we use two colors to show the smooth connection of the 2 formulations at Fn 0,4

SA-VPP Power Catamaran - Power to install

(according to the propulsion efficiency input)





Annex

Information about the sources of the computation :

For the friction drag and the aero drag :
State of the art formulations as for any boat project, for friction it is the ITTC57 formula for Cf with the Reynolds based on 0,7 Lw as recommended by Larsson & Eliasson in « Principles of Yacht design ». The key points being of course to have a right value of the wetted surface for the design displacement (for friction drag), of the frontal area and its global Cx (for the aero drag).

For the residuary drag :

Within this version 1.1, we use :

- Froude 0 to 0,25 : Holtrop-Mennen formulation named « Rw-A » (valid up to Froude 0,4) and hopefully also valid for slender monohull of Lw/Bw > 7
- Froude 0,25 to 0,4 : smooth transition between the 2 formulations
- Froude 0,4 between to 1,0 : Use of the available output data of model tests as reported by :

•P. van Oossanen in « Resistance prediction of small high-speed displacement vessels » where I picked up the ones for slender hulls (i.e. Lw/Bw > 7) in Series 64, SSPA series and NPL series.
•Molland & al. in « Resistance experiments on a systematic series of high speed catamaran forms – Variation on length-displacement ratio and breadth-draught ratio », the Southampton series.

Residuary drag for Froude < 0,4 :
From Holtop-Mennen formulation « Rw-A » in adimensional form (A means for Fn < 0,4) :

« Rw-A » / D ρ g = c1 c2 c5 Exp[m1 Fn^d + m4 Cos(λFn^-2)]

with,

c1 = 223105 c7^3,78613 (Tc/Bw)^1,07961 (90-i)^-1,37565

c7 = 0,229577 (Bw/Lw)^0,33333 when Bw/Lw < 0,11
c7 = Bw/Lw when 0,11 < Bw/lw < 0,25
c7 = 0,5 – 0,0625 (Lw/Bw) when Bw/Lw > 0,25

c2 = 1 (no bulbous bow taken into account)

c5 = 1 – 0,8 At / (Bw Tc Cms)

m1 = 0,0140407 (Lw/Tc) – 1,75254 (D^1/3 / Lw) – 4,79323 (Bw/Lw) – c16

c16 = 8,07981 Cp – 13,8673 Cp^2 + 6,984388 Cp^3 when Cp < 0,8
c16 = 1,73014 – 0,7067 Cp when Cp > 0,8

d = -0,9

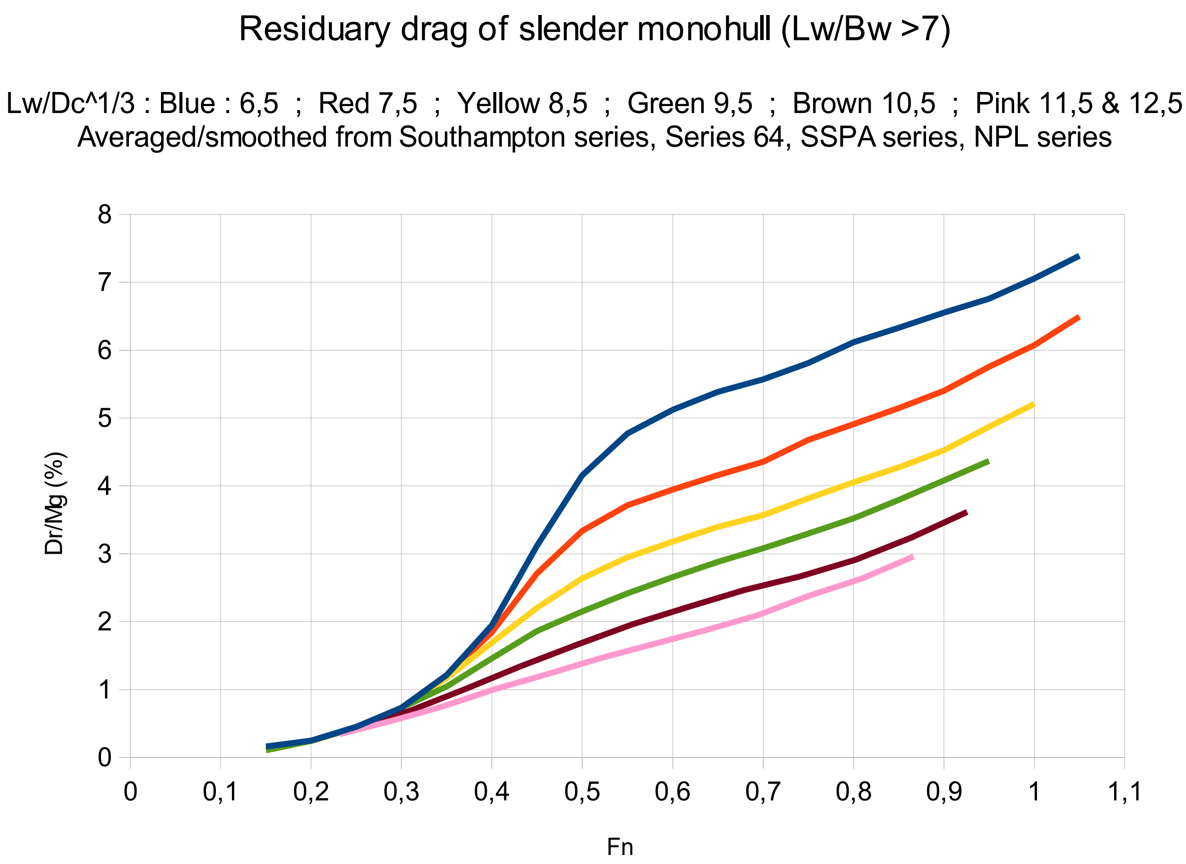
m4 = c15 0,4 Exp(-0,034 Fn^-3,29)

c15 = -1,69385 when Lw^3/D < 512
c15 = -1,69385 + (Lw/D^1/3 – 8)/2,36 when 512 < Lw^3/D < 1727
c15 = 0 when Lw^3/D > 1727

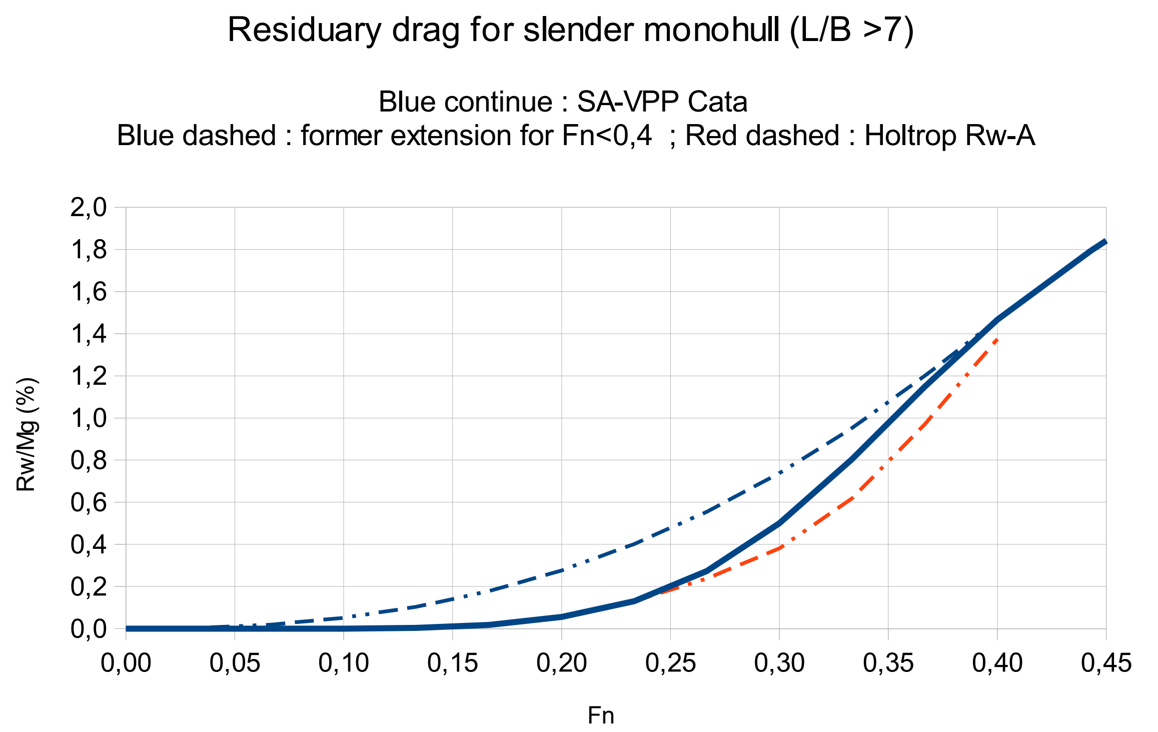
λ = 1,446 Cp – 0,03 (Lw/Bw) when Lw/Bw < 12
λ = 1,446 Cp – 0,36 when Lw/Bw > 12

Residuary drag for Froude 0,4 to 1,0 :
All the data from the Molland and Oossanen papers were put in same units and presented in the form of adimensional data and curves ready to use.

The key point for narrow monohulls of Lw/Bw > 7, highlighted by P. Oossanen in his paper and confirmed later on by Molland results was that, quoting P. Oossanen (page 219), «Up to Fn-value of about 0,9, the results for the 3 B/T values are almost identical, again leading to the observation that in the speed range of Fn 0,4 – 0,9 the length-displacement ratio is the only significant parameter », the LD ratio being Lw/Dc^1/3 (Lw waterline length, Dc displacement of the canoe body hull). The resulting curves are :



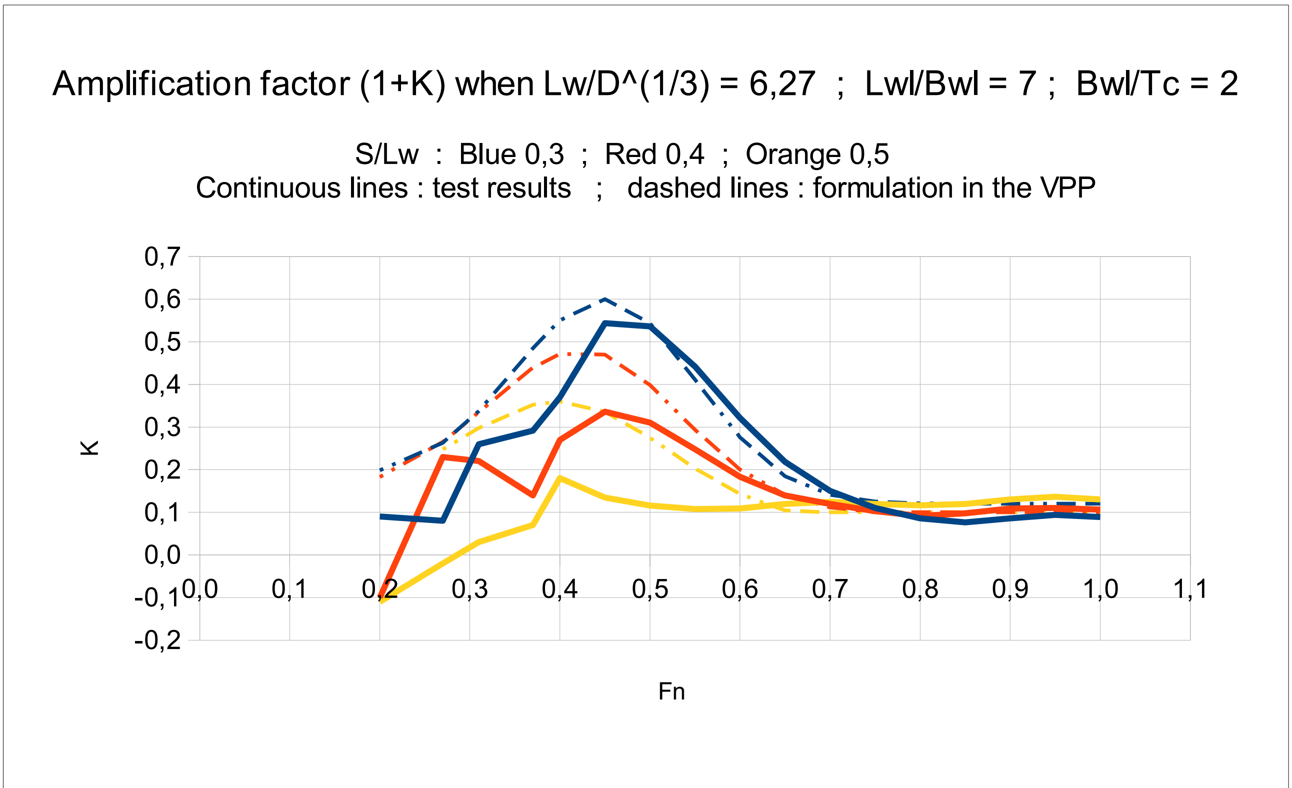
Smooth transition between Fn 0,25 and Fn 0,4, example :

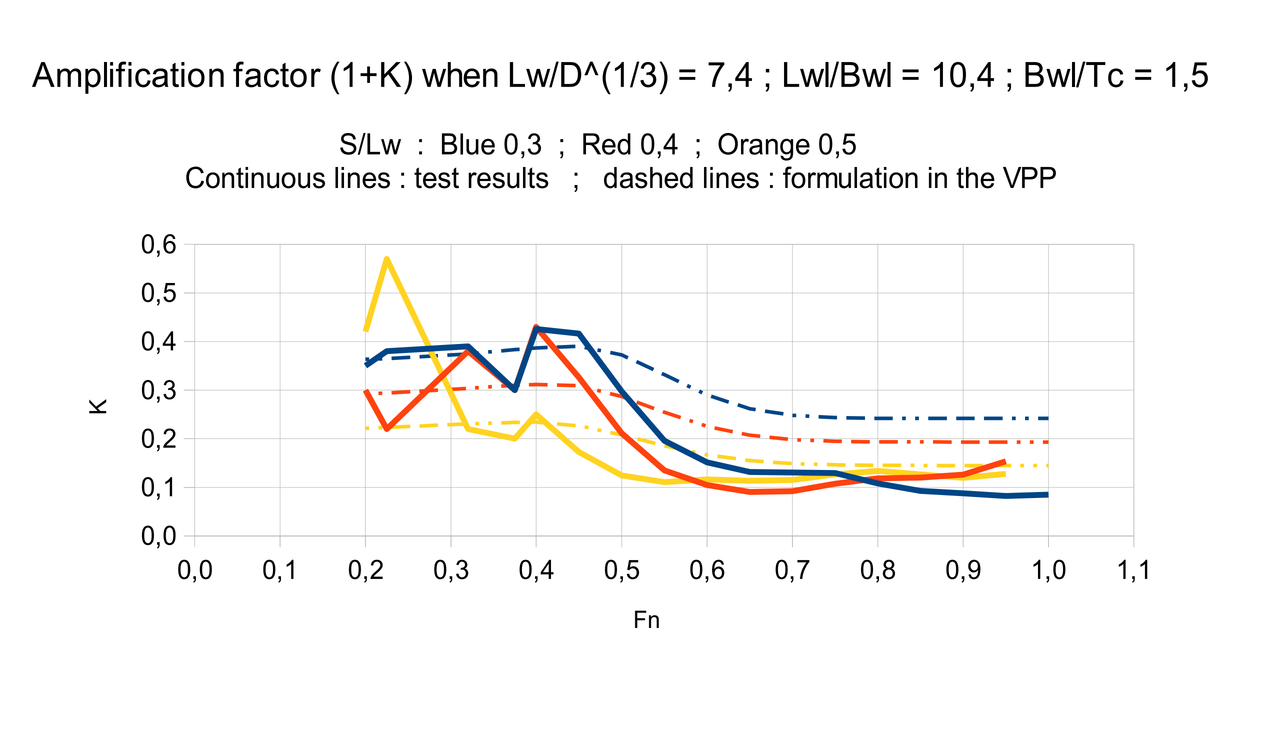


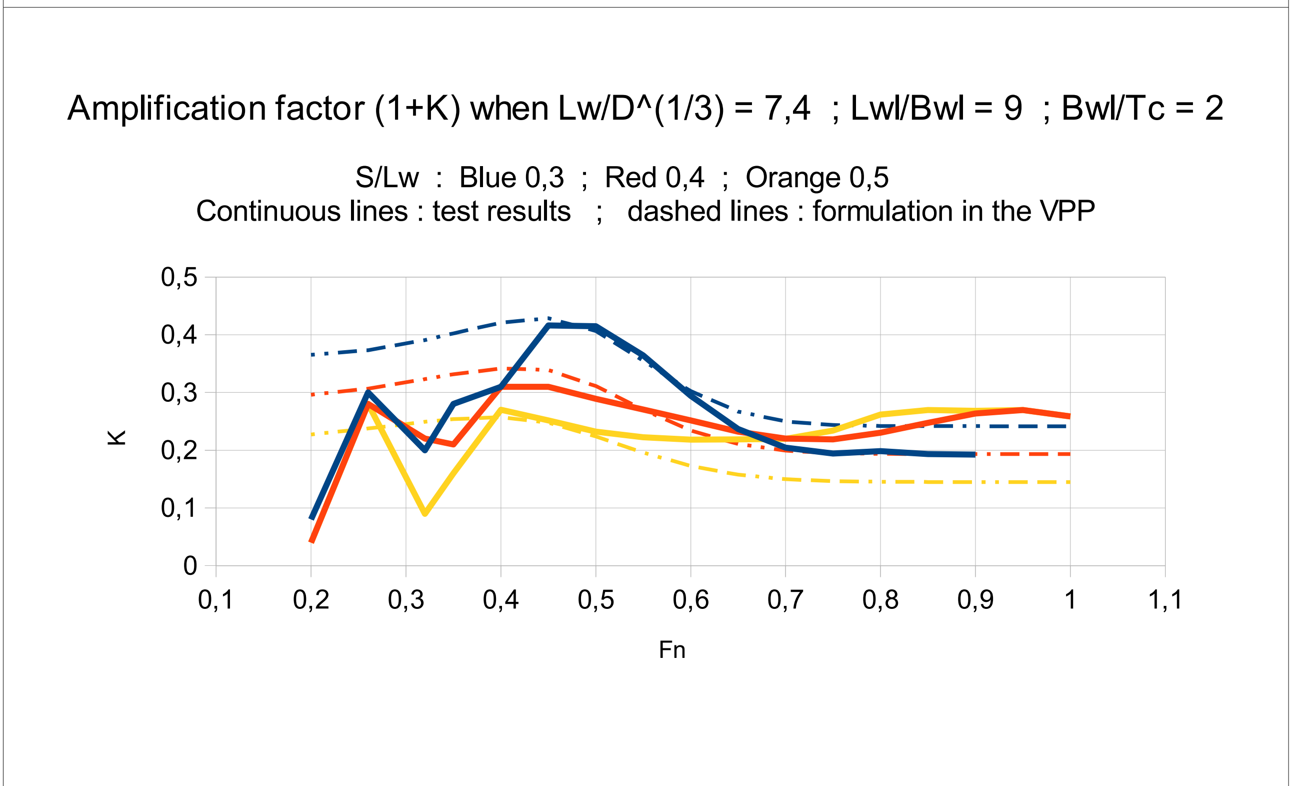
The other crucial point is the amplification factor 1+K due to interaction between the 2 hulls, fully adressed by Southampton series / Molland experiences in 1994 :

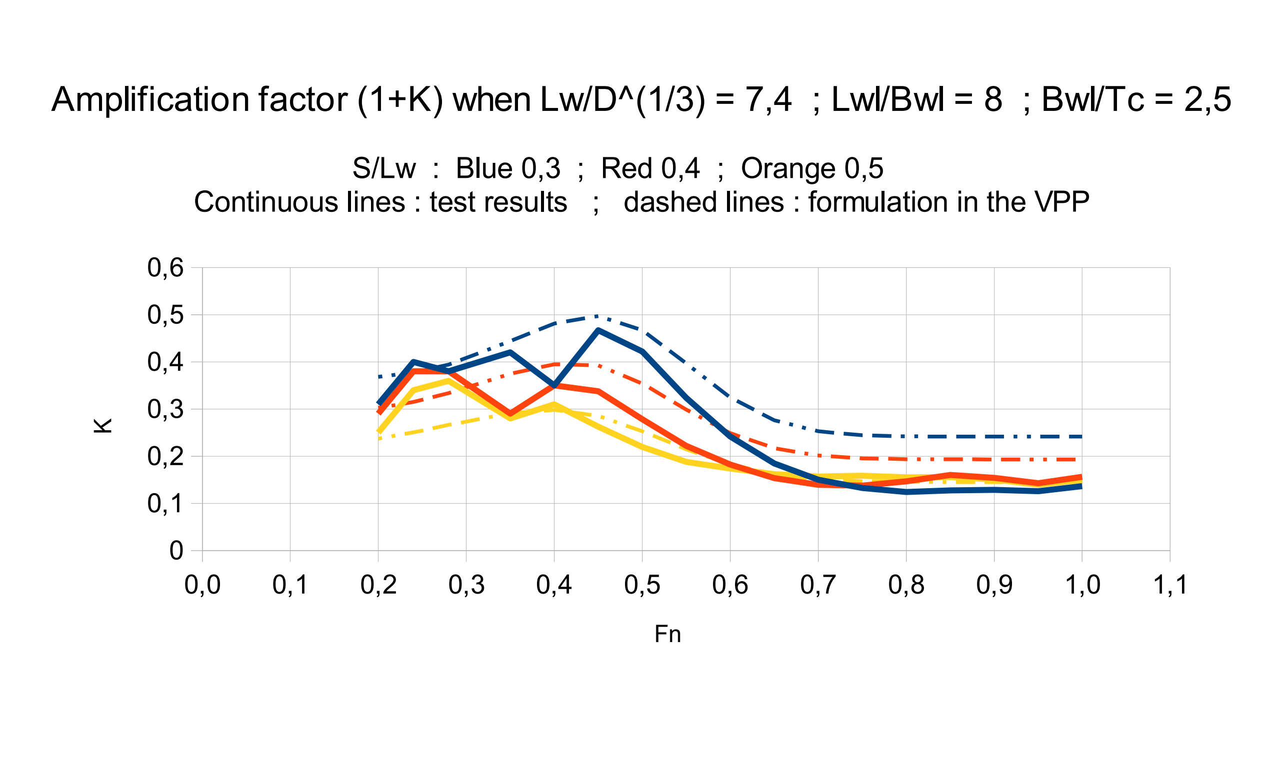
Residuary drag : Dr/Mg (%) Cata = (1+K) * Dr/Mg (%) Monohull

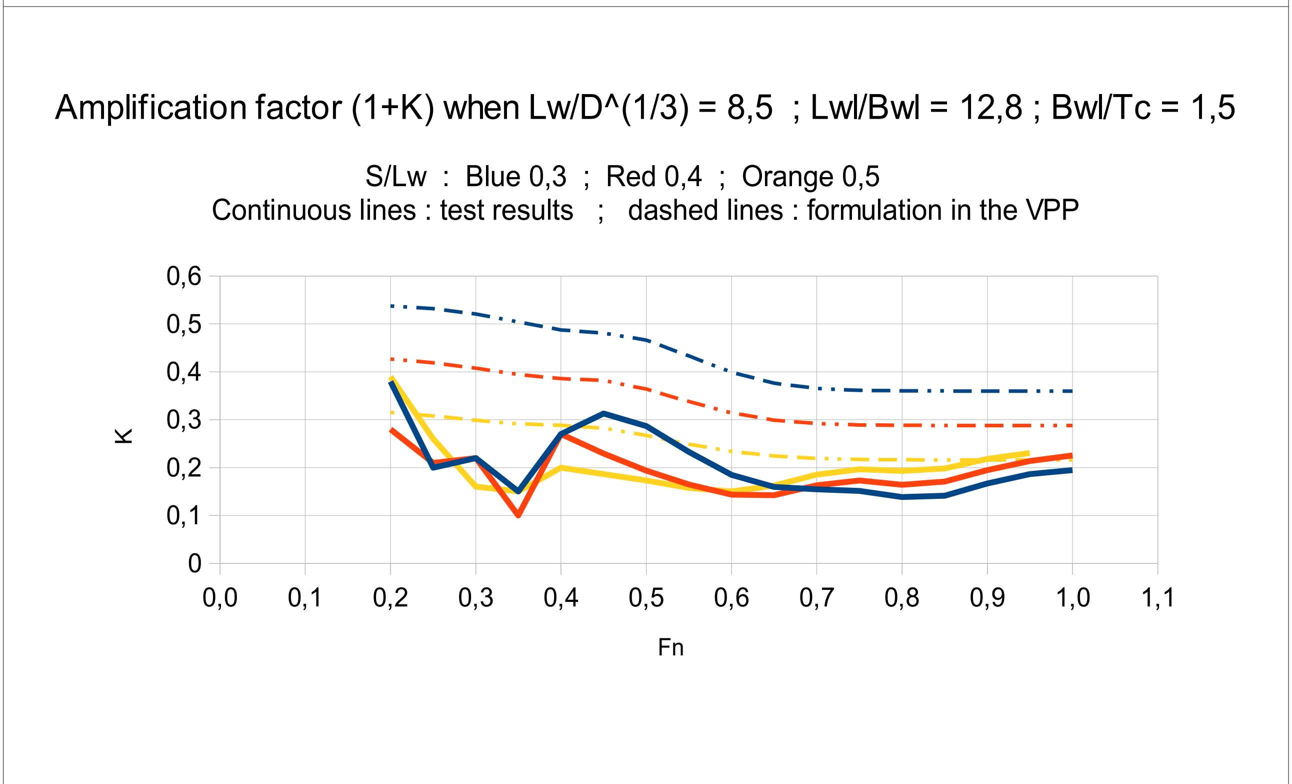
Here it is less simple to resume the respective role of Lw, Bw, Tc and Dc combined with S the space between hull axis >>> the embedded formulation in the VPP try to cover all the cases in a conservative manner. Especially, for Froude 0,2 to 0,4, the experimental results show a lot of steep humps and hollows of that factor whatever the parameters, including for large S/L (see Fig. 47 to 60 in the Molland paper), which are really challenging to represent by a numerical formulation. So the approach here is mostly to be conservative and to cover as much as possible the humps as the goal is oriented towards the estimation of the necessary power to install. You can see in the following figures the various test results compared with the programmed formulation, so that you can appreciate by yourself the approach :




Amplification factor (1+K) when Lw/D^(1/3) = 7,4 ; Lwl/Bwl = 10,4 ; Bwl/Tc = 1,5
S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP
K
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1,0 1,1
Fn

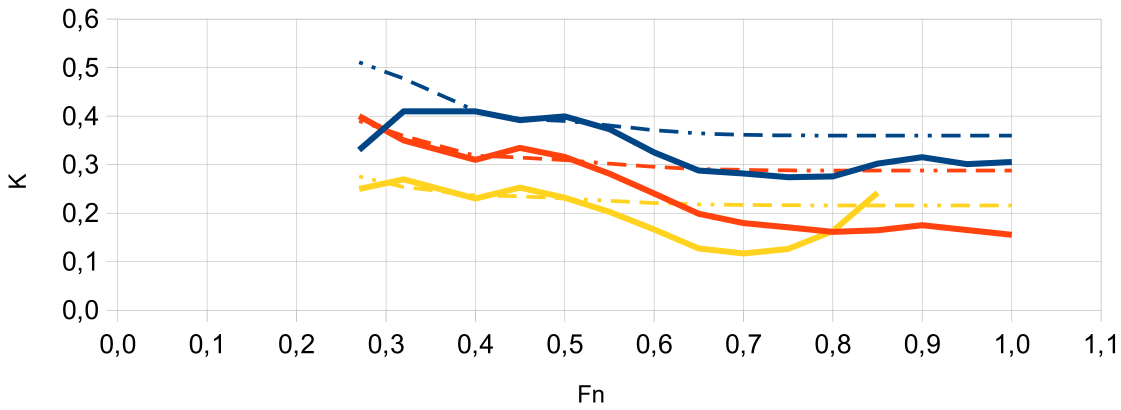

Amplification factor (1+K) when Lw/D^(1/3) = 7,4 ; Lwl/Bwl = 9 ; Bwl/Tc = 2
S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP
K
0
0,1
0,2
0,3
0,4
0,5
0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1 1,1
Fn


Amplification factor (1+K) when Lw/D^(1/3) = 7,4 ; Lwl/Bwl = 8 ; Bwl/Tc = 2,5
S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP
K
0,6
0,5
0,4
0,3
0,2
0,1
0
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
Fn


Amplification factor (1+K) when Lw/D^(1/3) = 8,5 ; Lwl/Bwl = 12,8 ; Bwl/Tc = 1,5
S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP
K
0,6
0,5
0,4
0,3
0,2
0,1
0
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
Fn

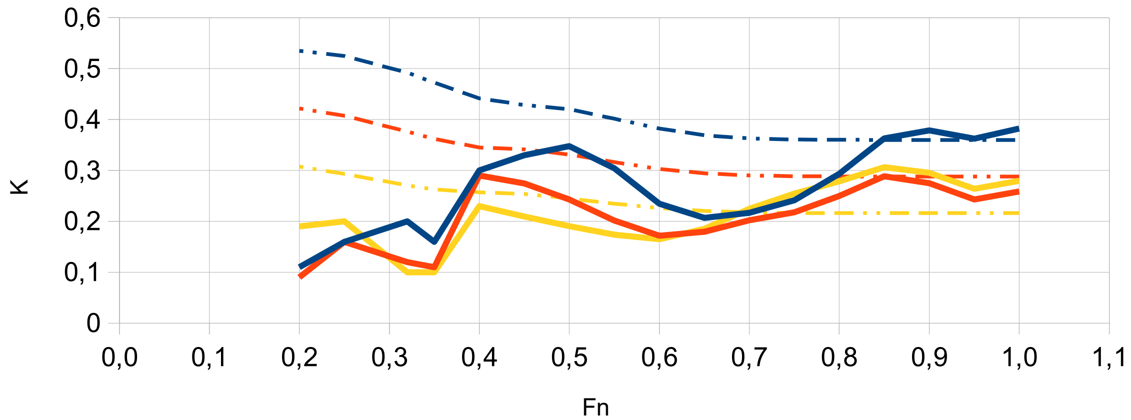
Amplification factor (1+K) when Lw/D^(1/3) = 8,5 ; Lwl/Bwl = 11 ; Bwl/Tc = 2

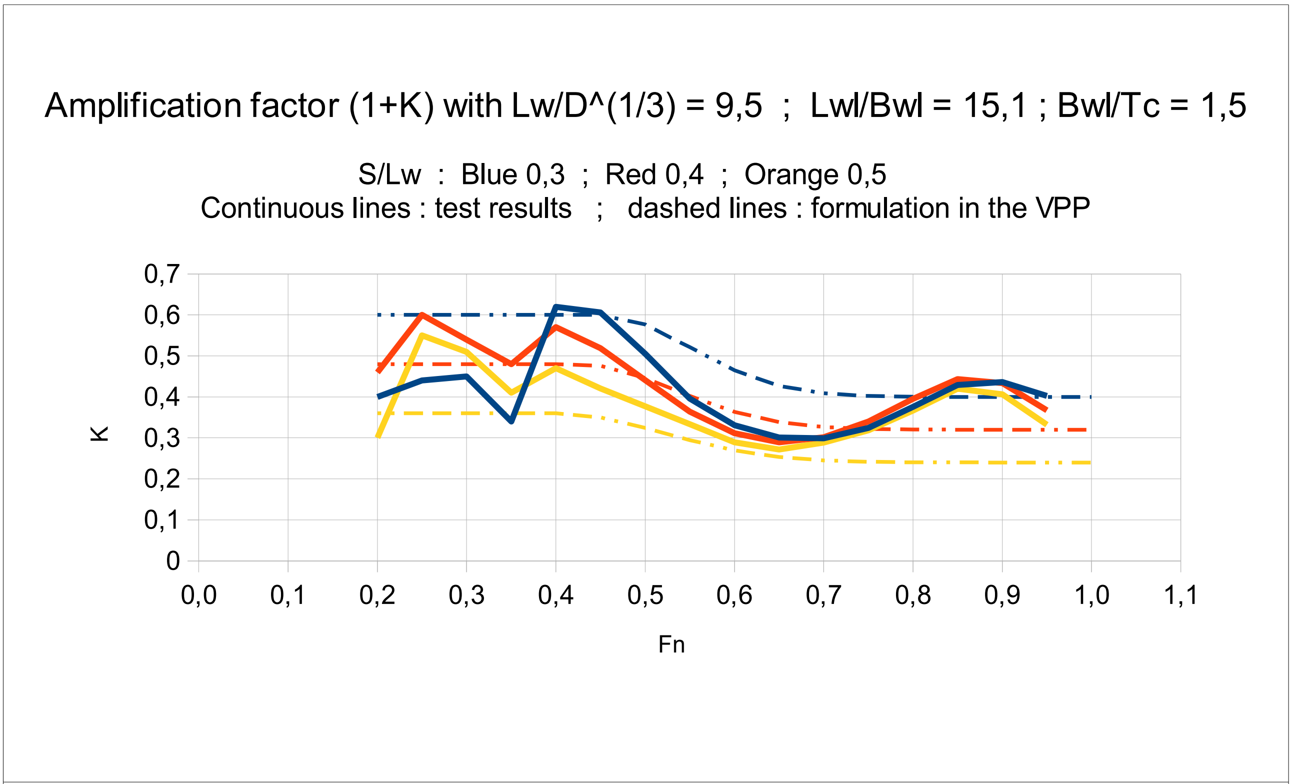
S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP

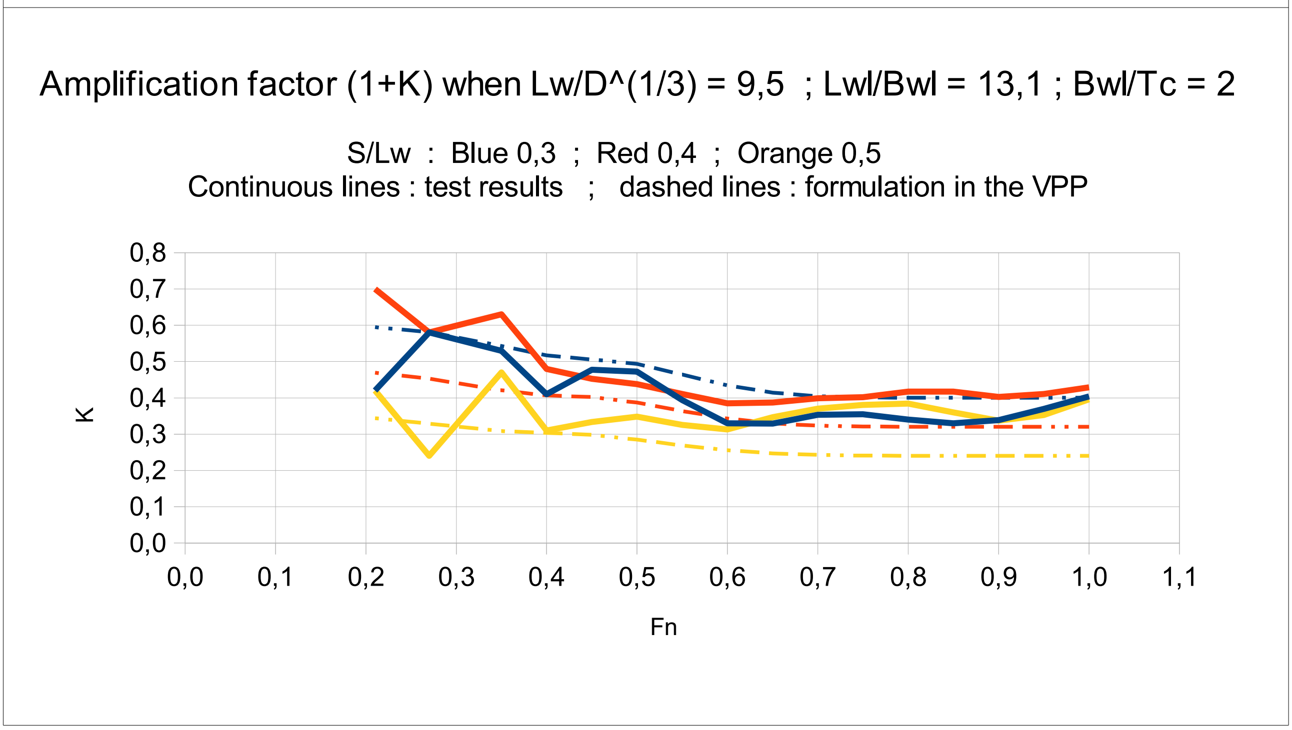


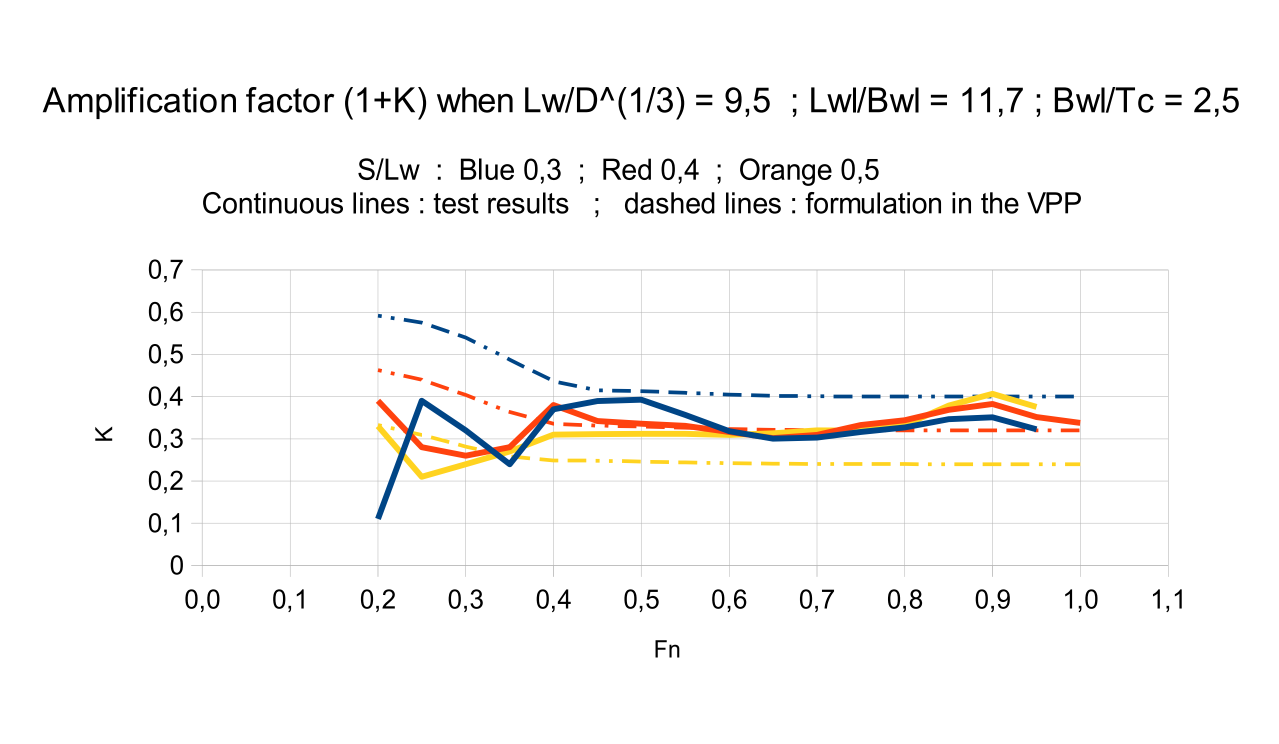
Amplification factor (1+K) when Lw/D^(1/3) = 8,5 ; Lwl/Bwl = 9 ; Bwl/Tc = 2,5

S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP




Amplification factor (1+K) with Lw/D^(1/3) = 9,5 ; Lwl/Bwl = 15,1 ; Bwl/Tc = 1,5
S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP
K
Fn
0,0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1,0 1,1
0 0,1 0,2 0,3 0,4 0,5 0,6 0,7


Amplification factor (1+K) when Lw/D^(1/3) = 9,5 ; Lwl/Bwl = 13,1 ; Bwl/Tc = 2
S/Lw : Blue 0,3 ; Red 0,4 ; Orange 0,5
Continuous lines : test results ; dashed lines : formulation in the VPP
K
Fn
0,0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1,0 1,1
0,0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8



Why no longer reliable for Fn > 0,9 -1,0 ? : because then the hulls are no longer primarily in displacement mode, dynamic lift forces occur, and then a lot of parameters like sections shape (circular or in U), Bw/Tc, trim, … can change the resulting drag.

Rear transom drag (additional pressure resistance due to the immersed transom)
From Holtrop-Mennen formulation :

Rtr = 0,5 ρ V^2 At c6

with ,

c6 = 0,2 (1 – 0,2 Fnt) when Fnt < 5
c6 = 0 when Fnt > 5

Fnt = V / [2 g At / (Bw + Bw Cwp)]^0,5 Froude number based on transom immersion