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A Comparison of Hull Resistances of a Mono-Hull and A SWATH Craft

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***Abstract*—The paper presents results of the investigation of a hull resistances for mono-hull and the SWATH patrol craft design concepts. Themono-hull resistance is estimated based on data of model experiments (SKLAD series) conducted by Brodarski Institutin Zagreb, Croatia. The SWATH resistance is estimated based on available data of existing ships as well as existing model tests data. The comparison showed that there is no significant difference in hull resistances for the two hull concepts. The results give very useful information's for the choice of a patrol craft design capable of reaching speeds of 30knots.**

Index Terms—**ship hull resistance, hydrodynamics, SWATH, mono-hull craft, ship design.**

I. INTRODUCTION

There is a long tradition of building patrol crafts in Croatian Shipyards for the Croatian Navy and many ships have been awarded worldwide for their properties and performances and have been successful through years of their operations in the Adriatic Sea. The standard mono-hull concept is more than 30 years old and some deficiencies have been noticed and confirmed [1]. One of the mayor problems is inability to operate on rough sees with high performance or even inability, for certain designs, to operate at all. Modern demands on naval ships in Croatia require that they should have broad capabilities, not only for survey and war operations, but also for control of the sea transport, repression of smuggling people and goods as well as other capabilities like participation in rescue missions and pollution prevention. These requirements condition some new design solutions for ability to perform various duties on rough seas as well as larger deck space for the installation of various equipment necessary for diverse operations and/or even modular deck parts. The multihull concept has been suggested as a potential solution. Twin hull catamarans have been pushing out conventional monohulls in passenger transportation for years, but regarding high performance requirements required for the patrol craft, they lack some operating capabilities [2]. The SWATH concept has been proposed as a solution. The problem with SWATH is lack of necessary design data, particularly regarding ship resistance, since there is very small number of units build worldwide and model tests are scarce. To compare two 'confronted' concepts it was necessary to estimate hull resistance and required thrust for the monohull and the SWATH design. The monohull resistance calculation was relatively straightforward, using available model tests data, but for the SWATH two approaches were used: the results of some model tests and available data of build ships.

II. SEMI DISPLACEMENT MONO-HULL

Calculation of the hull resistance and required power for the monohull concept is based on the results of model test data and experience with previously built ships.

A. The SKLAD Data Series

The SKLAD is a systematic series of 27 semi displacement models [3]. Basic hull form was defined based on experience and previous model tests as well as performance of already built ships (Figure 1). The series is developed on three models with different block coefficients, C_B, and various ratios of length at waterline L_{WL} and ship breadth, B_{WL} and draught T (Table 1) and for Froude numberF_{nV} from 1.0 to 3.0 given as

$$F_{n\nabla} = \frac{v}{\sqrt{g\nabla^{1/3}}} \qquad (1)$$

Where v is a ship speed [m/s], $g$is gravity acceleration [m/s^2] and ∇ is volume of a ship displacement in [m^3].

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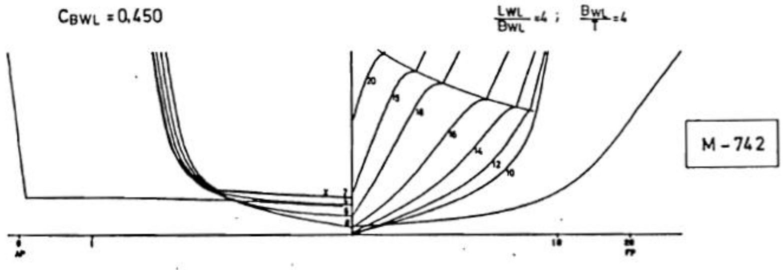

Fig 1 The hull form of the SKLAD model [3]

Table 1. Model characteristics for SKLAD systematic data series [3]

C_B=0,35		C_B=0,45		C_B=0,55	
L_{WL}/B_{WL}	B_{WL}/T	L_{WL}/B_{WL}	B_{WL}/T	L_{WL}/B_{WL}	B_{WL}/T
4	3	4	3	4	3
4	4	4	4	4	4
4	5	4	5	4	5
6	3	6	3	6	3
6	4	6	4	6	4
6	5	6	5	6	5
8	3	8	3	8	3
8	4	8	4	8	4
8	5	8	5	8	5

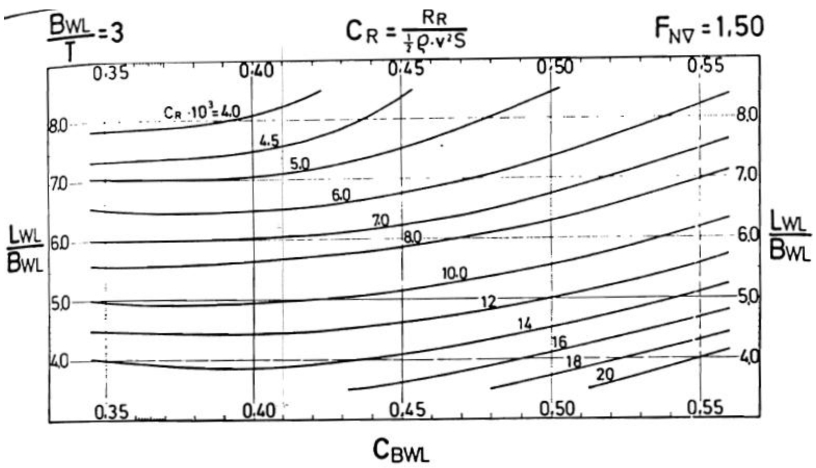

Fig 2 Example of the SKLAD data series diagrams [3]

B. *Estimation of the hull resistance*

The total resistance coefficient is defined by

$$C_T = C_F + C_R + \Delta C_T \qquad (2)$$

Where C_F is the friction resistance coefficient, $C_R$residuary resistance coefficient, is determined by means of the standard Froude method [lit], ΔC_T is correlation coefficient.

The friction coefficient is determined by ITTC-57 equation:

$$C_F = \frac{0,075}{(\log R_n - 2)^2} \qquad (3)$$

Where R_n is the Reynolds number $R_n = \frac{vL}{\nu}$ and ν is the kinematic viscosity of the seawater.

The correlation coefficient is given by [1]:

$$\Delta C_T = (14,77 - 0,7438 \ln R_n)/1000 \qquad (4)$$

Total hull resistance, R_T in [kN], is determined from:

$$R_T = \frac{1}{2} \rho S C_T v^2 \qquad (5)$$

Where ρ□ is seawater density in kg/m^3, S is wetted surface area in m^2- different for various speeds and draughts

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and calculated by the means of a computer.

Effective power is then $P_T = R$ and delivered power is $P_E =$, where η is coefficient of propulsion efficiency taken as 0.6.

Monohull particulars are: length overall $_{LOA}$=31.15m, length at design waterline L_{WL}=28.18m, breadth B=6.38 m, design draught T=1.54 m, displacement Δ=122 t and speed v=30.5 kn. The results of the hull resistance calculation are presented on Fig 3 and Fig 4.Total delivered power necessary for reaching design is 3595,4 kW.

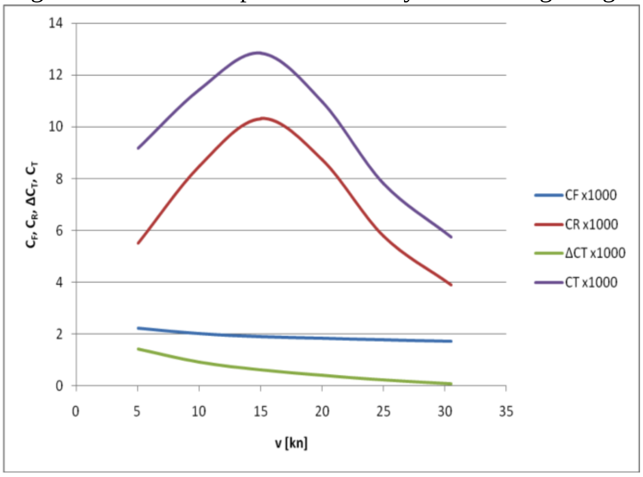

Fig 3 Calculated hull resistance coefficients

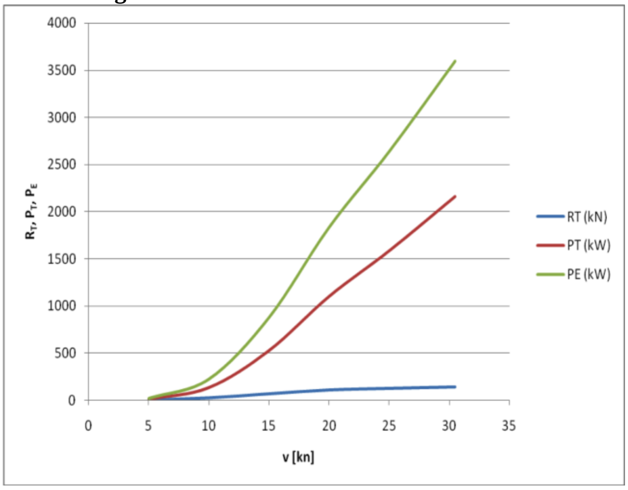

Fig 4 Total hull resistance, thrust and effective power of the mono-hull design

III. SWATH ANALYSIS AND DESIGN

The formulae for calculation of SWATH hull resistance and required power are the same as for the monohull ship (i.e. 1 to 5). The approach to the estimation of the residuary resistance coefficients, however, is significantly different. One obvious approach would be to test models in basin, which is too expensive in the early ship design phase. Another approach could be numerical simulation by the means of computers and CFD (Computational Fluid Dynamics) software. Experience with the use of the CFD has showed so far that the results of such analyses are valid predominantly for comparison of the same types of hulls prior to model tests [4]. Approach used in this investigation consisted of combined use of some model tests [5] and available data of already built SWATH ships.

A. Estimation of hull resistance

Total hull resistance for the SWATH hull is divided into friction resistance, C_F and residuary resistance C_R [2] and calculated according to formula (2). C_F is calculated according to formula (3) and the problem that remains is how to estimate C_R. Another issue regarding calculation of hull resistance of the SWATH ships is whether it has single strut on each submerged part or there are two struts (Fig 5). Both strut-designs have been considered here.

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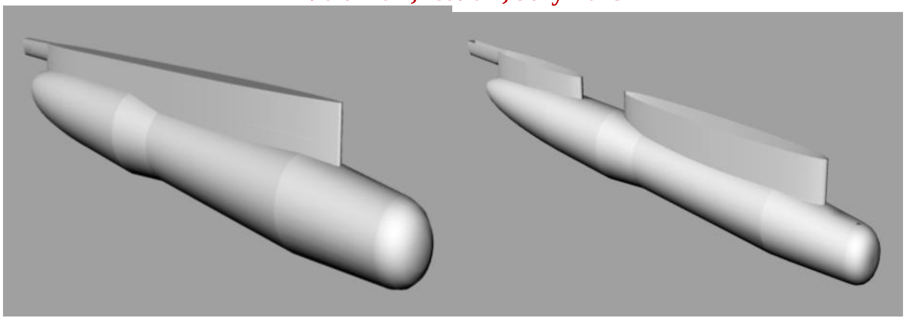

Fig 5 A single strut SWATH concept (left) and two-strut design (right)

Various data about already built ships had been gathered and analyzed. The most important data were dimensions, speed and installed power.

Table 2. Main data of built SWATH ships

Ship	L_{OA} [m]	B [m]	T [m]	Δ [t]	v [kn]	P [kW]
Skrunda	25,71	13,00	2,70	132,9	20,00	1618
Jakob Prei	26,10	13,00	2,70	132,9	20,00	1618
Perseus	25,20	13,00	2,70	125,0	18,00	1420
Ad Hoc 24m	26,93	9,80	2,03	75,0	25,00	1800
Ad Hoc 41m	48,00	16,90	3,70	375,0	28,00	7200
MC-ASD	20,00	9,60	1,50	60,0	14,00	676
FOB SWATH	25,00	10,60	2,49	100,0	22,85	1800
Planet	73,00	25,00	6,80	3500,0	15,00	4160
SWATH OPV	49,35	19,00	4,55	900,0	20,00	7600
MV China Star	131,00	32,30	8,40	12880,0	14,00	11340
Silver Cloud	41,00	17,80	4,10	600,0	14,00	1640
Elbe	49,90	22,55	5,90	1500,0	14,00	2000
Dose, Duhnen	25,20	13,00	2,70	125,0	18,00	1420
Kilo Moana	57,00	27,00	7,60	2588,0	15,00	3000
Sea Fighter	79,90	22,00	3,60	950,0	55,00	44800

Table 3. Measures of submerged hulls of built SWATH ships

Ship	L [m]	D [m]	b [m]	L_{WL} [m]	S [m^2]
Skrunda	23,82	2,15	11,00	19,65	300
Jakob Prei	23,75	2,08	11,00	20,10	300
Perseus	23,63	2,05	11,00	19,51	300
Ad Hoc 24m	22,00	1,50	8,30	23,50	220
Ad Hoc 41m	41,25	2,72	14,20	41,00	670
MC-ASD	18,06	1,53	7,60	17,77	190
FOB SWATH	24,63	2,47	8,00	18,32	310
Planet	69,37	6,16	20,00	60,55	2400
SWATH OPV	46,00	3,50	15,00	45,85	1100
MV China Star	122,63	7,00	24,20	117,65	6000
Silver Cloud	38,00	3,20	14,60	35,95	770
Elbe	46,49	4,23	18,30	42,75	1400
Dose, Duhnen	23,50	2,00	11,00	19,50	300
Kilo Moana	52,61	6,52	20,50	52,83	1800
Sea Fighter	71,46	2,57	19,40	73,00	1000

Where L is length of a submerged hull, D is an approximate diameter of submerged hull, b is spacing between hulls and S is calculated wetted surface area.

By analyzing installed power and speeds and by the use of computer programs it was possible to assess residuary resistance coefficients for ships in table 2.

Table 4. Estimated resistance and power of considered ships

Ship	η	P_T [kW]	R_T [kN]	C_Tx1000	C_Rx1000
Skrunda	0,60	970,8	94,36	5,79	3,86

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Jakob Prei	0,60	970,8	94,36	5,79	3,87
Perseus	0,55	781,0	84,35	6,39	4,43
Ad Hoc 24m	0,60	1080,0	83,98	4,50	2,67
Ad Hoc 41m	0,60	4320,0	299,93	4,21	2,54
MC-ASD	0,60	405,6	56,32	11,14	9,08
FOB SWATH	0,60	1080,0	91,88	4,18	2,27
Planet	0,55	2288,0	296,53	4,05	2,32
SWATH OPV	0,55	4180,0	406,30	6,80	5,08
MV China Star	0,60	6804,0	944,79	5,92	4,32
Silver Cloud	0,60	984,0	136,64	6,67	4,80
Elbe	0,55	1100,0	152,74	4,10	2,28
Dose, Duhnen	0,55	781,0	84,35	6,39	4,43
Kilo Moana	0,55	1650,0	213,84	3,89	2,14
Sea Fighter	0,60	26880,0	950,09	2,31	0,88

Here η is 0.6 for ships with standard diesel-mechanical propulsion and 0.55 for the diesel-electric propulsion systems. The same methodology was used for all analyzed ships; however since the data in Table 2 may possibly be inaccurate it was necessary to use additional analysis to assess residuary resistance coefficients.
Another approach used in this research was estimation of aresiduary resistance based on data obtained from model tests performed in Kyrilov institute [5]. These tests were performed on three basic models with length/draught ratios 9, 15 and 24. Also, the residuary resistance coefficient include correlation and additionally the tests were performed with single submerged hulls first (to determine resistance) and then with two submerged hulls thus including the interaction between hulls, measured by interaction coefficient *I*, in the resistance calculation. The residuary coefficient is then determined as:

$$C_R = IC_{R1} \tag{6}$$

Where C_{R1} is coefficient obtained by tests. Models, test procedure details as well as resulting diagrams are explained in [5].
By the use of resulting resistance diagrams and applying those to the ships in Table 2. it was possible to assess necessary resistance coefficients.

Table 5. Estimated resistance coefficients of analyzed SWATH ships

Ship	C_{R1} x1000	I	C_{RS} x1000
Skrunda	4,79	1,053	5,04
Jakob Prei	4,61	1,050	4,84
Perseus	5,25	1,070	5,62
Ad Hoc 24m	2,51	0,995	2,50
Ad Hoc 41m	2,70	1,080	2,92
MC-ASD	7,20	1,220	8,78
FOB SWATH	3,85	1,110	4,27
Planet	6,70	1,170	7,84
SWATH OPV	5,46	1,470	8,03
MV China Star	2,06	0,810	1,67
Silver Cloud	3,30	1,150	3,80
Elbe	3,57	1,150	4,11
Dose, Duhnen	5,08	1,065	5,41
Kilo Moana	4,60	1,130	5,20
Sea Fighter	0,90	1,320	1,19

In addition to above analysis a comparison of one strut vs. two struts was performed by means of computer programs and well known resistance calculation methods: Holtrop, Fung and Slender Body (S.B).The results are in accordance with existing knowledge [6, 7].

B. The SWATH design

Based on the previous analysis it was possible to design a SWATH craft in accordance with design demands, i.e. speed 30kn and displacement of 120 t. Since the number of struts was not an issue when talking about hull resistance, a two-strut design was selected (Fig 6). That choice was done primarily because of a little better stability of two-strut designs over single strut designs. Main dimension are: L_{OA} = 25.5m, B = 13.0 m, T = 2.6m,

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L_{WL} = 19.5m, L_H = 23.0m, D_H = 2.0m, $L_{Strut-bow}$ = 8.75m, $L_{strut-stern}$ = 7.75m, S = 310m^2, b/L = 0.478. The results of the hull resistance analysis are shown in the table 6.

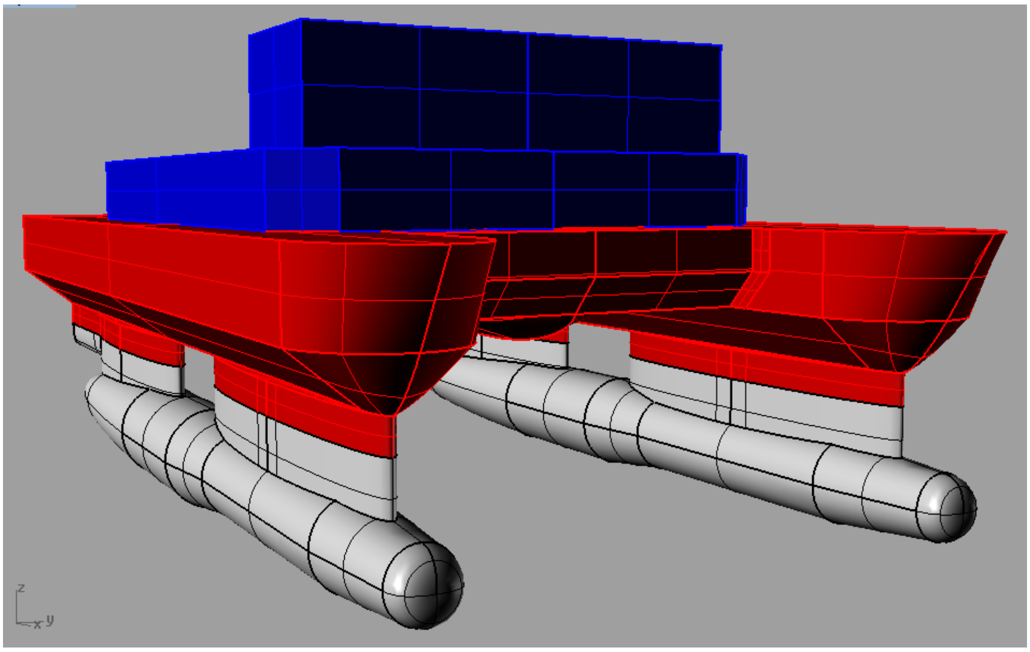

Fig 6 SWATH design

Table 6. Resistance and power of the proposed SWATH design

v [kn]	R_T [kN]	P_T[kW]	η	P_E[kW]
5	3,13	8,05	0,6	13,41
10	21,88	112,55	0,6	187,58
15	94,62	730,11	0,6	1216,84
20	105,97	1090,26	0,6	1817,10
25	118,10	1518,75	0,6	2531,25
30	143,27	2210,98	0,6	3684,97

Above described procedure for the estimation of the hull resistance was applied on the selected design and the comparison is given in the next chapter.

IV. COMPARISON OF THE TWO DESIGNS

The comparison of the two concepts is presented in Table 7 and on Figure 7 and Figure 8.

Table 7. Comparison of total resistance and delivered power

	mono-hull		SWATH	
v [kn]	C_T *x1000*	P_E[kW]	C_T *x1000*	P_E[kW]
5	9,18	22,253	3,19	13,41
10	11,45	226,243	5,58	187,58
15	12,85	877,713	10,72	1216,84
20	10,98	1832,591	6,75	1817,10
25	7,81	2635,715	4,82	2531,25
30	5,75	3594,512	4,06	3684,97

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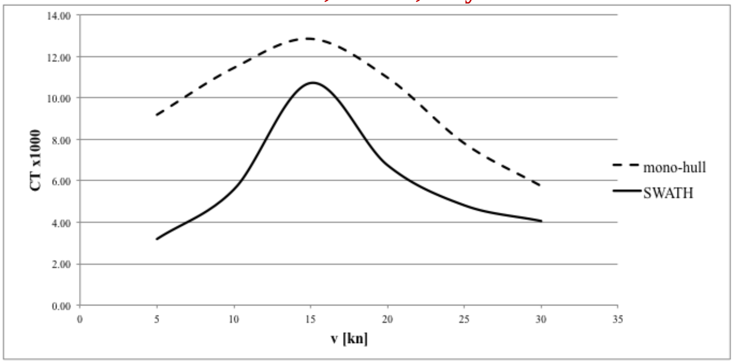

Fig 7Comparison of the total resistance coefficients

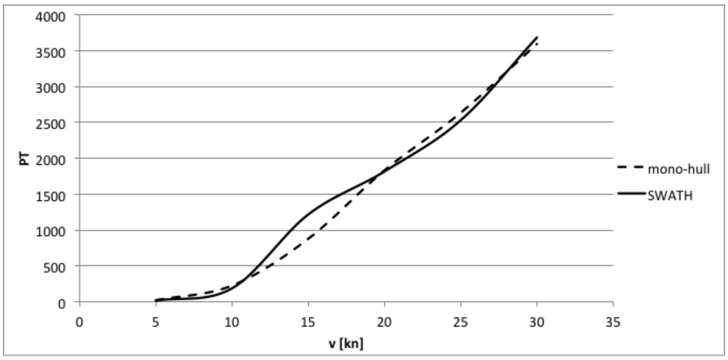

Fig 8Comaprison of the delivered power

V. CONCLUSION

Developed simple procedure for estimation of SWATH ship hull resistance, described in the paper, was successfully applied and based on it a preliminary design of the SWATH patrol craft, with properties equivalent to those of the mono-hull design, was presented. The comparison of the total hull resistance of a mono-hull semi displacement craft and a SWATH craft showed that a matter of choice of a SWATH design over mono-hull design for a patrol craft can't be based on a total hull resistance and with that related the total necessary power installed on ship and in perspective the fuel consumption. The choice should be based on other properties and demands. Excellent stability and sea keeping properties, larger breadth (more space on decks) and ability to operate in full capacity on rough seas are very important advantages of SWATH ships [8]. On the other hand complex machinery installation and maintenance as well as large draught (compared to mono-hull) are disadvantages.

REFERENCES

[1] M. Šuljić, "Determination of priorities in design of lightweight, fast, patrol crafts", Master thesis, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, 1992.

[2] S. Kos,D. Brčić,and V. Frančić, "Comparative analysis of conventional and SWATH passenger catamaran", research report, University of Rijeka, 2009.

[3] A. Gamulin, "Systematic series of semi displacement ships - SKLAD", Brodarski institute, Zagreb, 1995.

[4] The Specialist Committee on CFD in Marine Hydrodynamics, Final Report, 26th ITTC Conference, Rio de Janeiro, Brazil, 28 August - 3 September, 2011.

[5] V. A. Dubrovsky, K. I. Matveev, "Small watreplane area ship models: Re-analysis of test results based on scale effect and form drag", Ocean engineering 33, pp 950-963, 2006.

[6] T. G. Lang, J. E. Sloggett, "SWATH developments and performance comparisons with other craft", International conference on SWATH ships and advanced multi-hulled vessels, London, 1985.

[7] R. Dinsmore, "Small SWATH research vessels", 2000.

[8] F. Granneman, "SWATH – A proven and innovative hull concept", Abeking &Rasmussen Schiffsund Yachtwerk Aktiengesellschaft, 2011.

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