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PRELIMINARY HYDRODYNAMIC ANALYSES FOR A RIVER RESEARCH SHIP. COMPARATIVE STUDY OF MONO-HULL AND CATAMARAN SHIP TYPE

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ABSTRACT

The design in early stages of the ships involves several preliminary hydrodynamic analyses, also for the ship operating on river waterways, IN(1.2) navigation class. This technical paper includes two main parts as preliminary assessment for the design constructive versions of a river research ship. The first part is focused in the comparative study of the mono-hull and the catamaran ship design by seakeeping and global strength criteria. The second part is focused on the ship resistance for two mono-hull versions of the river research ship. The study hydrodynamic preliminary results are the initial bases for proper design in next steps of the river research ship.

Keywords: preliminary analyses, seakeeping, ship resistance, global strength, river research ship.

1. INTRODUCTION

From early design stages hydrodynamic criteria by preliminary analyses are used in order to decide the design version, in this paper applied for a river research ship hull.

The paper is structured in two main parts, mono-hull (MH) and catamaran (KA) comparative study by seakeeping and global strength criteria, ship resistance comparative study of two versions for the mono-hull type (MH1, MH2).

2. COMPARATIVE STUDY OF MONO-HULL AND CATAMARAN DESIGN

The preliminary hydrodynamic analyses are developed for simplified prismatic ship shapes with mono-hull (Fig.1) and catamaran (Fig.2) design, having the main characteristics presented in Table 1. The analyses involve preliminary hydrodynamic models implemented by own codes DYN(OSC) [1] for seakeeping and P_QSW [2] for strength.

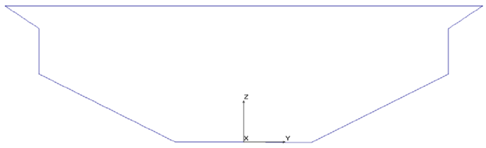


Fig.1 The midship-lines mono-hull type (*MH*).

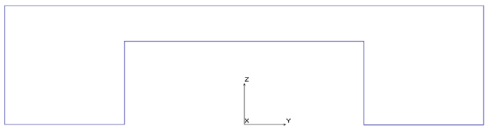


Fig.2 The midship-lines catamaran type (*KA*).

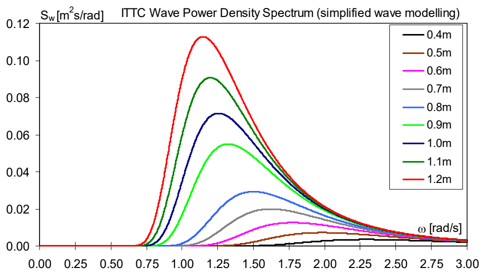


Fig.3 Averaged wave spectra, IN(1.2).

Table 1. Mono-hull and catamaran data.

Type:		MH	KA
L[m]	max.length	44.5	
B[m]	max.breadth	10.5	12
b_P[m]	bodies distan.	-	6
b[m]	breadth z=0	3	2 x 3
x_G[m]	LGC	22.25	
z_G[m]	VGC	2.5 ; 3.5	
H[m]	height	3	
h_P[m]	bodies height	-	2.1
T[m]	draught	1.5	
Δ[t]	displacement	400.5	
v[km/h]	speed	0 ; 20	
ρ[t/m^3]	water density	1.000	
μ[deg]	heading angle	90 ; 180	
ω[rad/s]	wave freq.	0-3 rad/s (0.001)	
Hs[m]	wave height	IN(1.2)	
simplified mass distribution - uniform			
simplified shape		Fig.1	Fig.2
hydrostatic diagrams – nonlinear approach			
hydro. model RAO		lin. strip	approx.
seakeeping short term – ITTC spectra (Fig.3)			
global strength by 1D-beam approach			

The numerical results for the preliminary hydrodynamic comparative analysis of the mono-hull and the catamaran ship types for the river research vessel with simplified shapes, are presented in the following:

-Fig.4.1-4 the hydrostatic diagrams;
-Fig.5.1-2 the sagging and hogging wave free surface, head wave IN(1.2);
-Fig.6.1-4 global strength, head waves, vertical bending moments and shear forces;
-Fig.7.1-3 the heave response amplitude operator functions;
-Fig.8.1-2 the pitch response amplitude operator functions;
-Fig.9.1-2 the roll response amplitude operator functions;
-Fig.10.1-3 the heave short term response;
-Fig.11.1-3 the heave acceleration response;
-Fig.12.1-2 the pitch short term response;
-Fig.13.1-2 the pitch acceleration response;
-Fig.14.1-2 the roll short term response;
-Fig.15.1-2 the roll acceleration response;

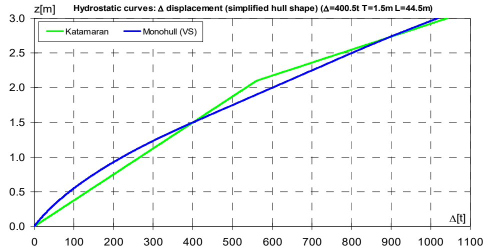


Fig.4.1 Hydrostatics – displacement Δ[t].

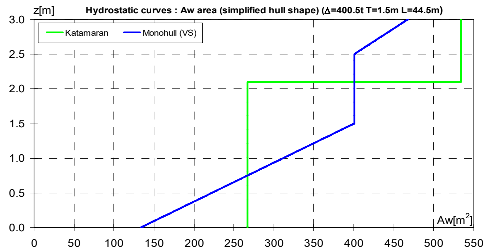


Fig.4.2 Hydrostatics–water plane area Aw[m^2].

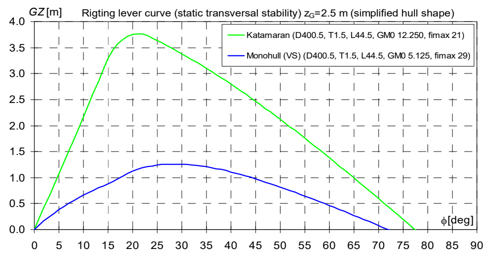


Fig.4.3 Hydrostatics – GZ[m], z_G=2.5m.

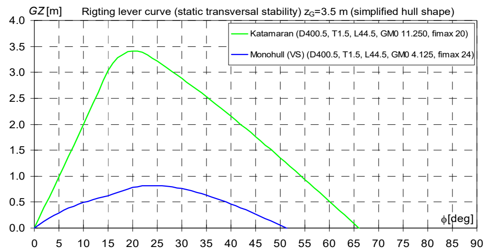
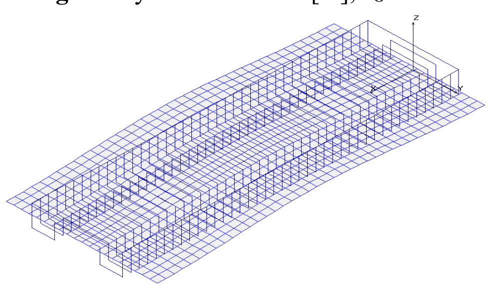


Fig.4.4 Hydrostatics – GZ[m], z_G=3.5m.



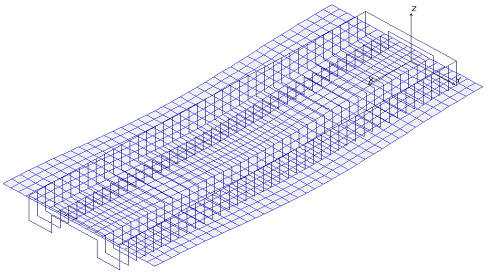


Fig.5.1 Wave hogg. & sagg., KA, IN(1.2).

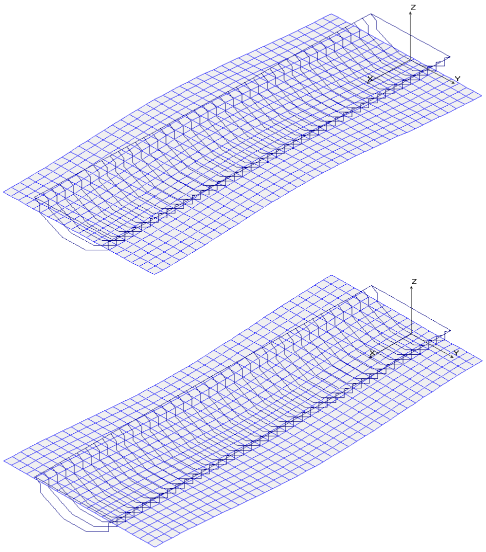


Fig.5.2 Wave hogg. & sagg., MH, IN(1.2).

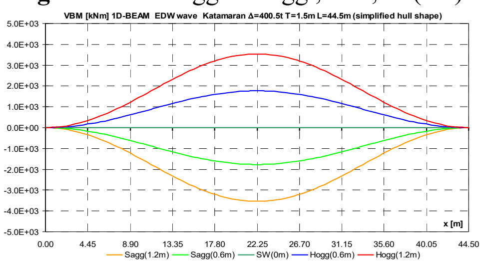


Fig.6.1 Strength global, *VBM* [kNm], KA.

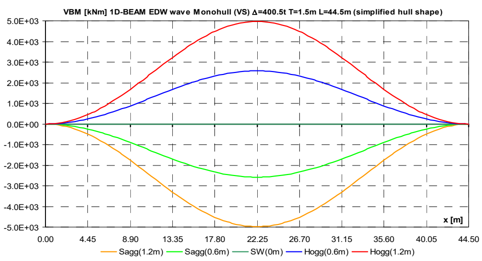


Fig.6.2 Strength global, *VBM* [kNm], MH.

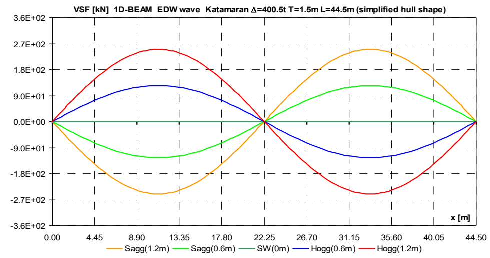


Fig.6.3 Strength global, *VSF* [kN], KA.

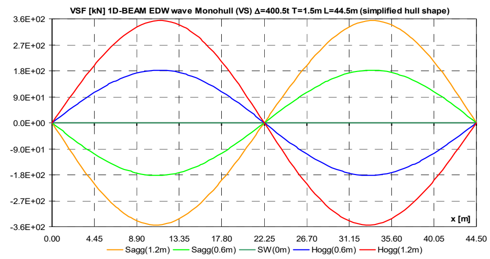


Fig.6.4 Strength global, *VSF* [kN], MH.

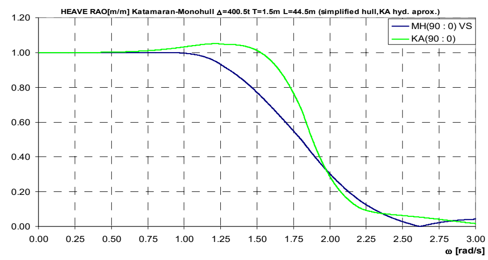


Fig.7.1 Heave *RAO*[m/m], μ=90 deg,v= 0 km/h

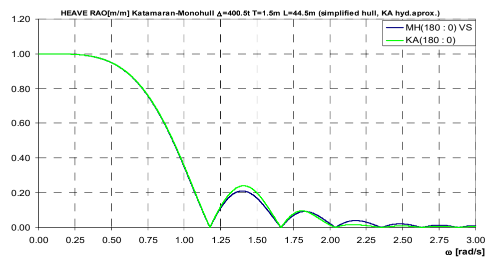


Fig.7.2 Heave *RAO*[m/m], μ=180deg,v= 0km/h

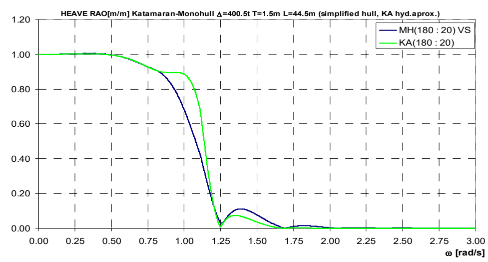


Fig.7.3 Heave *RAO*[m/m],μ=180deg,v=20km/h

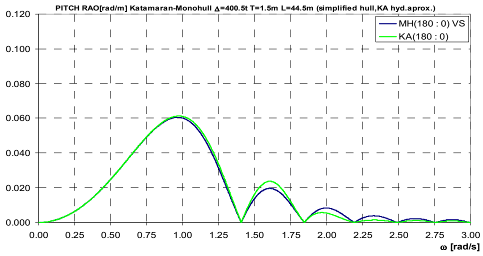


Fig.8.1 Pitch *RAO*[rad/m], μ=180deg,v=0 km/h

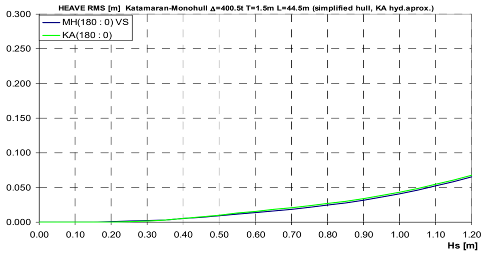


Fig.10.2 Heave *RMS*[m], μ=180 deg,v= 0 km/h

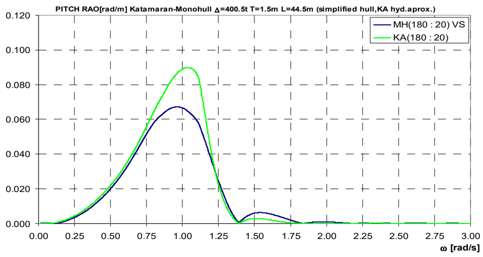


Fig.8.2 Pitch *RAO*[rad/m], μ=180deg,v=20km/h

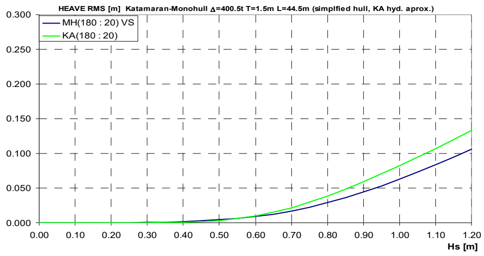


Fig.10.3 Heave *RMS*[m], μ=180deg,v=20 km/h

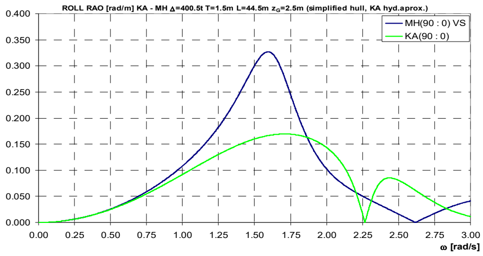


Fig.9.1 Roll *RAO*[rad/m],μ=90deg,v=0,z_G=2.5m

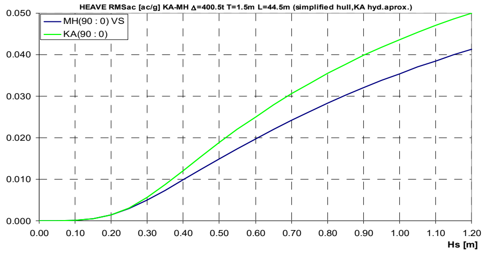


Fig.11.1 Heave *RMSac*[ac/g], μ=90, v= 0

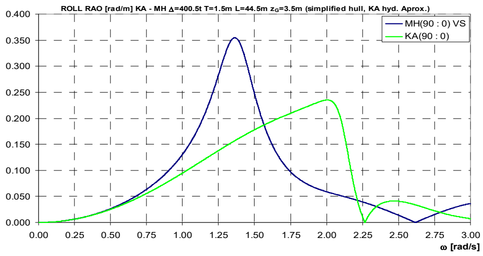


Fig.9.2 Roll *RAO*[rad/m],μ=90deg,v=0,z_G=3.5m

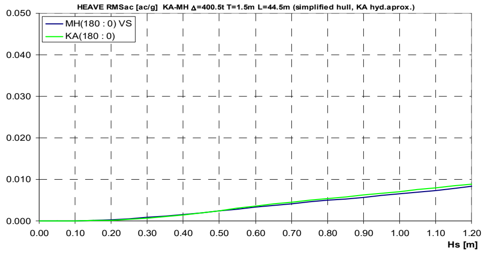


Fig.11.2 Heave *RMSac*[ac/g], μ=180, v= 0

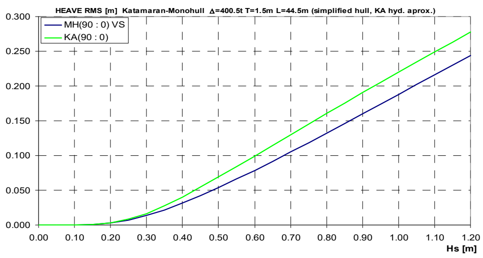


Fig.10.1 Heave *RMS*[m], μ=90 deg,v= 0 km/h

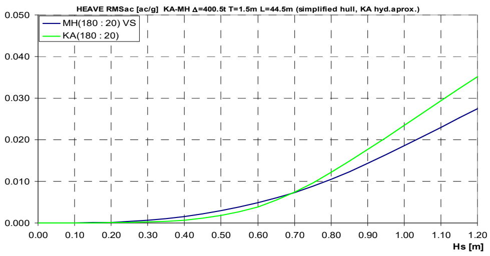


Fig.11.3 Heave *RMSac*[ac/g], μ=180, v=20

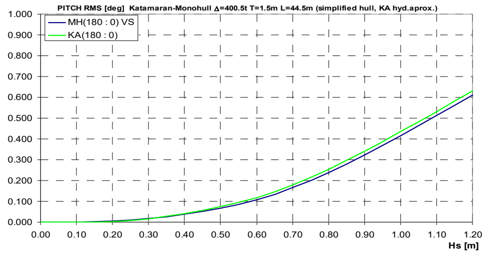


Fig.12.1 Pitch *RMS*[deg], μ=180 deg,v= 0 km/h

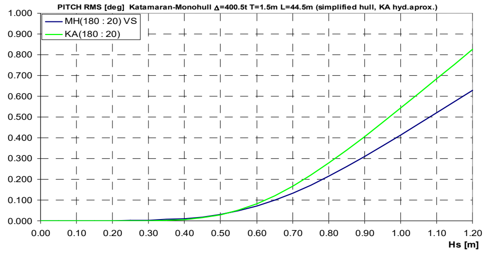


Fig.12.2 Pitch *RMS*[deg], μ=180deg,v=20km/h

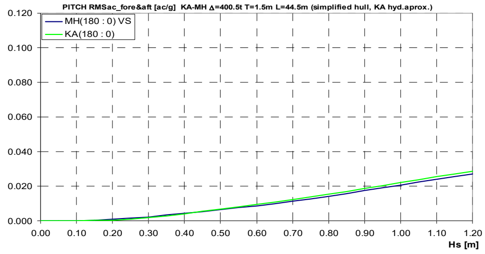


Fig.13.1 Pitch *RMSac*[ac/g], μ=180,v= 0, A-F

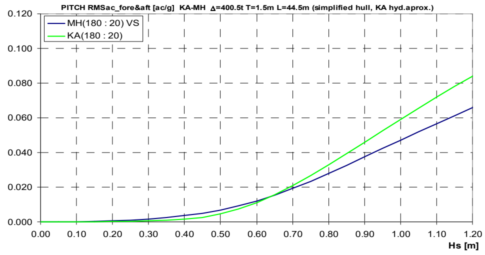


Fig.13.2 Pitch *RMSac*[ac/g], μ=180,v= 20, A-F

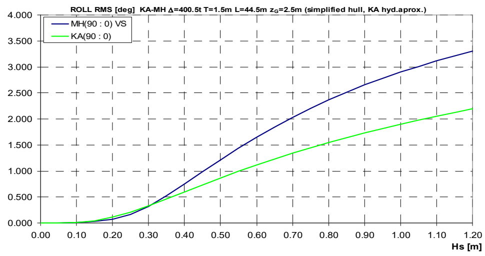


Fig.14.1 Roll *RMS*[deg], μ=90,v= 0, z_G=2.5m

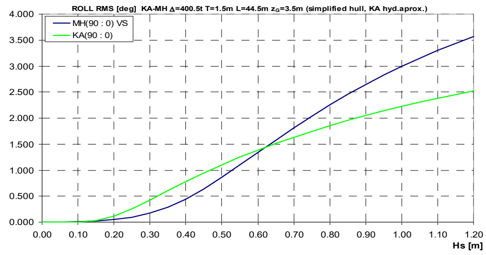


Fig.14.2 Roll *RMS*[deg], μ=90,v= 0, z_G=3.5m

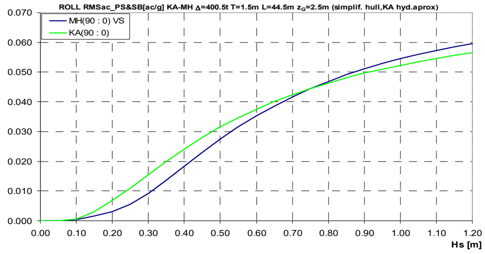


Fig.15.1 Roll *RMSac*[ac/g],μ=90,v= 0,z_G=2.5m,S

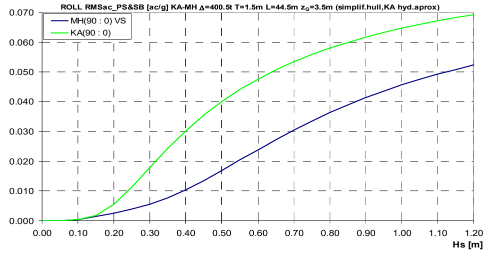


Fig.15.2 Roll *RMSac*[ac/g],μ=90,v= 0,z_G=3.5m,S

In Tables 2 and 3 are included in synthesize the numerical results of the preliminary comparative hydrodynamic analyses of the mono-hull (MH) and catamaran (KA).

The intact stability (3), global strength (4), roll *RAO* (6), roll short term response *RMS* (11) criteria are in favor of the catamaran.

The onboard space (1), heave and pitch *RAO* (5), heave short term response *RMS* (7), heave acceleration short term response *RMSac* (8), pitch short term response *RMS* (9), pitch acceleration short term response *RMSac* (10), roll acceleration *RMSac* (12) for z_G=3.5m, criteria are in favor of mono-hull.

The displacement (2) and roll short term response acceleration (12) for z_G=2.5m criteria are comparable satisfied by the mono-hull and catamaran hull versions.

Table 2. Catamaran preliminary analyses.

No.	Criterion	Figs	Results	Y/N
1	Space under the main deck	2,4.2	reduced	N
2	Displacement	3	≤ 1041.30 t	C
3	Intact stability	4.3,4.4	11.25-12.25 m	Y
4	Global strength EDW IN(1.2)	5.1, 6.1,6.3	3.5E+3 kNm 2.5E+2 kN	Y
5	Heave and pitch RAO	7.1-3 8.1-2	larger	N
6	Roll RAO	9.1-2	more reduced	Y
7	Heave RMS (FB > 0.3m)	10.1-3	0.2775 m	N
8	Heave acc. RMS (< 0.1g)	11.1-3	0.0501·g	N
9	Pitch RMS (< 1.5 deg)	12.1-2	0.8294 deg	N
10	Pitch acc. RMS (aft-fore <0.1g)	13.1-2	0.0841·g	N
11	Roll RMS (< 4 deg)	14.1-2	2.1968 deg 2.5244 deg	Y
12	Roll acc. RMS (sides < 0.1g)	15.1-2	0.0564·g 0.0693·g	C N

Table 3. Mono-hull preliminary analyses.

No.	Criterion	Figs	Results	Y/N
1	Space under the main deck	1,4.2	significant	Y
2	Displacement	3	≤ 1017.94 t	C
3	Intact stability	4.3,4.4	4.12-5.12 m	N
4	Global strength EDW IN(1.2)	5.2, 6.2,6.4	5.0E+3 kNm 3.5E+2 kN	N
5	Heave and pitch RAO	7.1-3 8.1-2	more reduced	Y
6	Roll RAO	9.1-2	larger	N
7	Heave RMS (FB > 0.3m)	10.1-3	0.2438 m	Y
8	Heave acc. RMS (< 0.1g)	11.1-3	0.0413·g	Y
9	Pitch RMS (< 1.5 deg)	12.1-2	0.6294deg	Y
10	Pitch acc. RMS (aft-fore <0.1g)	13.1-2	0.0657·g	Y
11	Roll RMS (< 4 deg)	14.1-2	3.3044 deg 3.5686 deg	N
12	Roll acc. RMS (sides < 0.1g)	15.1-2	0.0596·g 0.0532·g	C Y

3. COMPARATIVE STUDY OF MONO-HULLS BY SHIP RESISTANCE

The preliminary ship resistance analyses are developed for two mono-hulls, with fine shapes MH1 (Fig.16) and full shapes MH2 (Fig.17) design, having the main characteristics presented in Table 4. The preliminary ship resistance analyses are done by PHP–UGAL code [3], based on Holtrop-Mennen approach, and DELFTShip code[4], by statistical ship series data.

Table 4. Mono-hulls data MH1 & MH2.

Type:		MH1	MH2
L_{OA}[m]	ship lengths	44.5	
L_{BP}[m]		41.257	42.336
L_{WL}[m]		42.794 43.114	42.552 43.307
B[m]	maximum breadth	9	
H[m]	height	3	
T[m]	draught	1.500 1.800	1.337 1.500
Δ[t]	displacement	287.527 381.823	381.811 435.309
Sw[m^2]	wet surface	354.42 388.60	324.20 413.67
c_B	ship coefficients	0.4978 0.5467	0.7458 0.7443
c_P		0.6311 0.6637	0.7573 0.7548
c_W		0.7953 0.8280	0.8464 0.8491
c_M		0.7888 0.8236	0.9848 0.9862
v[kn]	speed	0 - 14	
v[km/h]		0 - 26	
ρ[t/m^3]	water density	1.000	
MD	design reserve	10%	
MS	service reserve	15%	
Hull shape from DELFTShip series prototypes		Fig.16 Fine shape	Fig.17 Full shape

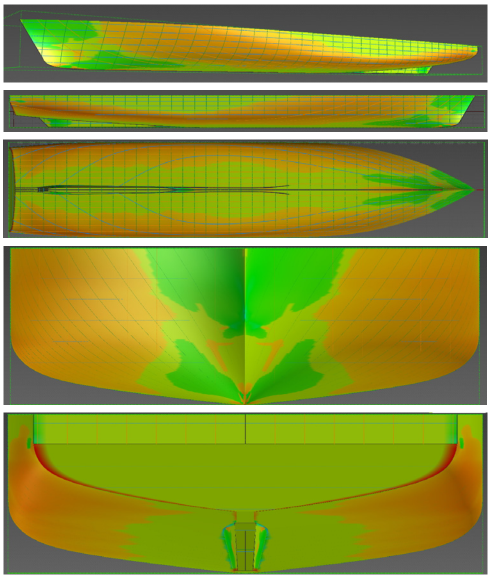


Fig.16 Offset lines mono-hull fine shape MH1

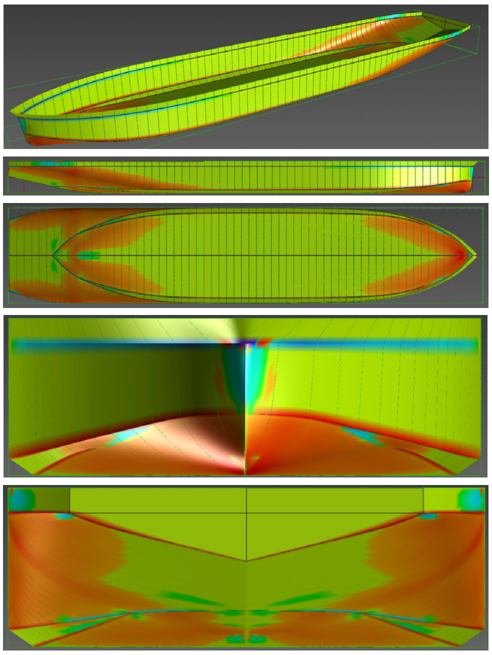


Fig.17 Offset lines mono-hull full shape MH2

The numerical results for the preliminary ship resistance comparative analysis of the two mono-hulls for the river research vessel with statistical ship series data are presented in the following:

-Fig.18 PB engine power, 90% MCR, mono-hull ship MH1 diagrams;
-Fig.19 PB engine power, 90% MCR, mono-hull ship MH2 diagrams;
- Table 5.1-2 The PB engine power for ship speed 7-14 kn, mono-hull ship MH1;
- Table 6.1-2 The PB engine power for ship speed 7-14 kn, mono-hull ship MH2.

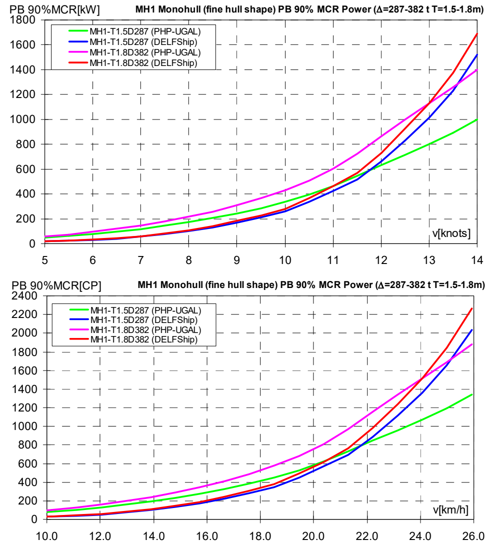


Fig.18 PB power, 90% MCR, ship MH1

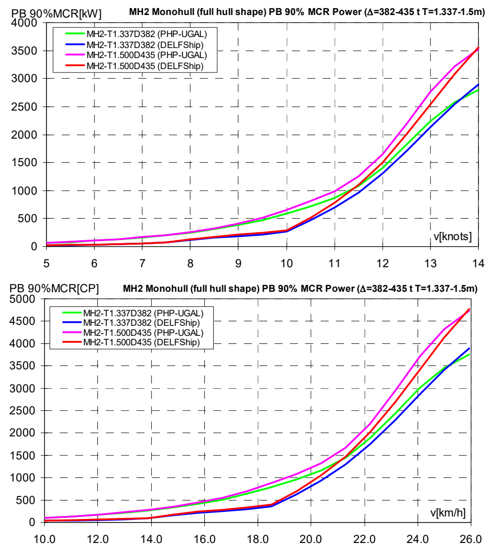


Fig.19 PB power, 90% MCR, ship MH2

Table 5.1 PB power, T=1.5 m, vessel MH1.

Method		PHP-UGAL		DELFTShip	
No.	v[kn]	PB[kW]	PB[HP]	PB[kW]	PB[HP]
1	7	118.09	158.35	55.87	74.93
2	8	172.25	230.99	100.70	135.04
3	9	243.49	326.53	168.95	226.57
4	10	335.91	450.46	259.05	347.40
5	11	463.82	621.99	423.73	568.23
6	12	630.18	845.09	660.95	886.34
7	13	799.47	1072.11	1013.63	1359.31
8	14	997.85	1338.13	1518.75	2036.67

Table 5.2 PB power, T=1.8 m, vessel MH1.

Method		PHP-UGAL		DELFTShip	
No.	v[kn]	PB[kW]	PB[HP]	PB[kW]	PB[HP]
1	7	146.41	196.34	60.03	80.50
2	8	214.95	288.26	108.34	145.29
3	9	307.31	412.10	182.32	244.50
4	10	430.79	577.70	280.80	376.56
5	11	604.40	810.52	461.54	618.93
6	12	862.04	1156.02	730.09	979.07
7	13	1129.92	1515.25	1130.16	1515.57
8	14	1401.27	1879.13	1689.84	2266.11

Table 6.1 PB power,T=1.337m, vessel MH2.

Method		PHP-UGAL		DELFTShip	
No.	v[kn]	PB[kW]	PB[HP]	PB[kW]	PB[HP]
1	7	161.53	216.62	53.08	71.18
2	8	248.91	333.79	117.33	157.34
3	9	381.03	510.96	186.45	250.04
4	10	589.79	790.93	266.06	356.79
5	11	867.14	1162.85	702.10	941.53
6	12	1402.27	1880.47	1308.20	1754.33
7	13	2240.16	3004.11	2134.27	2862.10
8	14	2802.04	3757.60	2900.76	3889.98

Table 6.2 PB power, T=1.5 m, vessel MH2.

Method		PHP-UGAL		DELFTShip	
No.	v[kn]	PB[kW]	PB[HP]	PB[kW]	PB[HP]
1	7	166.37	223.11	57.38	76.95
2	8	260.88	349.84	124.68	167.19
3	9	409.80	549.55	209.76	281.30
4	10	655.75	879.37	294.50	394.92
5	11	990.78	1328.65	785.41	1053.26
6	12	1649.30	2211.74	1506.31	2020.00
7	13	2761.69	3703.49	2546.71	3415.19
8	14	3528.21	4731.41	3557.22	4770.31

In Table 7 are included in synthesize the numerical results of the preliminary ship resistance analyses of the two mono-hulls.

Table 7 PB power, 90%MCR, MH1 & MH2.

MH	T [m]	Δ [t]	v [kn]	v [km/h]	max.PB [kW]	max.PB [HP]
1	1.500	287.53	11	20.372	463.82	621.99
			13	24.076	1013.63	1359.31
	1.800	381.82	11	20.372	604.40	810.52
			13	24.076	1130.16	1515.57
2	1.337	381.81	11	20.372	867.14	1162.85
			13	24.076	2240.16	3004.11
	1.500	435.31	11	20.372	990.78	1328.65
			13	24.076	2761.69	3703.49

4. CONCLUSIONS

From the comparison between the catamaran and the mono-hull by seakeeping and global strength criteria, results that the mono-hull type is to be selected for the river research vessel design (Tables 2 and 3).

The preliminary ship resistance has pointed out that for reference speed around 20 km/h and Δ≈382t the mono-hull river research vessel requires a PB power between 2 x 302 kw (2 x 405 HP) and 2 x 434 kw (2 x 582 HP), function to the hull shape type (Table 7).

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