Quest Journals
Journal of Architecture and Civil Engineering
Volume 7 ~ Issue 8 (2022) pp: 34-45
ISSN(Online) : 2321-8193
www.questjournals.org

Research Paper

Design Analysis of Ship HullPreliminary Hydrostatic Properties(Case Study: Offshore Patrol Boat)

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Abstract
Ship hydrostatics estimation is very important in the early stage of design analysis of a ship. The aim of this paper is to estimated the preliminary ship hydrostatic measurement (values) for an offshore patrol boat with principal dimensions of length overall (66.06m), length on waterline (63.26m), length between perpendicular (61m), immerse depth on water (4.7m) and draft of water (3.2m) which will enable the naval architects to have knowledge of the properties of the boat on still water. The materials used in this work is hull geometry of an offshore patrol boat to estimate the properties of the boat. Were various methods which was developed from experiment and mathematical model were used to calculate the measurement (values) of the boat preliminary design properties on still water and result obtained express correlation satisfaction with statistical proof test. The result was further validated with Maxsurf Software were boat result agrees, observation indicated that the higher the precision, accurate the result for best fit curves for ship hull is obtained for ship hydrostatics preliminary design.
Key Word: *Design, Ship, Hydrostatics, Hull, Offset*

R**eceived 11 August, 2022; **R**evised 24 August, 2022; **A**ccepted 26 August, 2022 © The author(s) 2022. **P**ublished with open access at **www.questjurnals.org

I. Introduction

Shipbuilding make us to understand that shipbuilding encompasses a large number of features and it is subjected to different areas and loading condition.Thus, naval architects need to known the mission statement of the ship to enable the naval architects evaluate the ship principal dimensions, ship hull geometry and the loading features of the ship,which led to study of its hydrostatic properties for best fit selection curves for ship hull. The ship hull is water tight with reserve buoyancy base on load line estimation (draft) and the primary function of a ship are classified into three categories, namely industrial mission, commercial mission and servicing mission, in which speed and fuel consumption are the paramount consideration to evaluate the efficiency. This means that the external hull of the ship must move with least resistance, design speed and pay load on water. The shape of a ship hull is an irregular and complex surfacethat cannot be describe, to redeem the feature of the complex ship hull shape is that the ship hull must be viewed from three dimension curvature, body plan (stations in the transverse direction), sheer profile (buttock lines in the longitudinal direction) and half breath (water lines in the vertical direction) and this can further be illustrated by an offset table known as the ship hull geometry. This stations, water lines and buttock lines are the fundamental to estimate hydrostatic properties of the ship hull at different waterlines.

II. Overview

The seaworthiness of any floating ship has always presented some serious challenge to the Naval Architect. This paper will review the ship hydrostatics properties that were in existence few decades ago, design principles and experimental results with model tests to the growing trend of empirical, numerical and technological advancement and the modern incorporation of high-speed computers.

2.1 Extent of Past Work[1]

[1]

The strong, watertight construction and durability attribute of floating structures, structurally enabling it to survive at sea was never really an issue to the old boat builders,archaeological evidence, the use of log boat, raft boat and primitive boat. Evidences from ancient Egypt shows how the early Egyptians improved the above names boats, later the Greeks and others introduces similar design with the aid of documented boat principal dimensions, boat hull geometry and boat hydrostatic properties of the primitive boat, with gradual development which led to adoption of iron and steel, which gave birth to modern shipbuilding. Result of shipbuilding make us to understandthe important of ships hydrostatics properties in ship preliminary design. Furthermore, early scholar developed mathematical model fromnumerical andexperimental results for estimating ship hydrostatic properties which gave birth to modern ship hydrostatic software due to the advancement in technology.

III. Materials and Methods

3.1 The principal dimensions represent the size and major features of the patrol boat and include the following items in fig 3.1 below

Length overall (L_{OA})	66.06	m
Length on water line (L_{WL})	63.701	m
Length between perpendicular (L_{PP})	61.00	m
Breath molded	11.50	m
Depth molded	4.70	m
Draught Molded	3.2	m
Station spacing	6.1	m
Camber	0.075	m

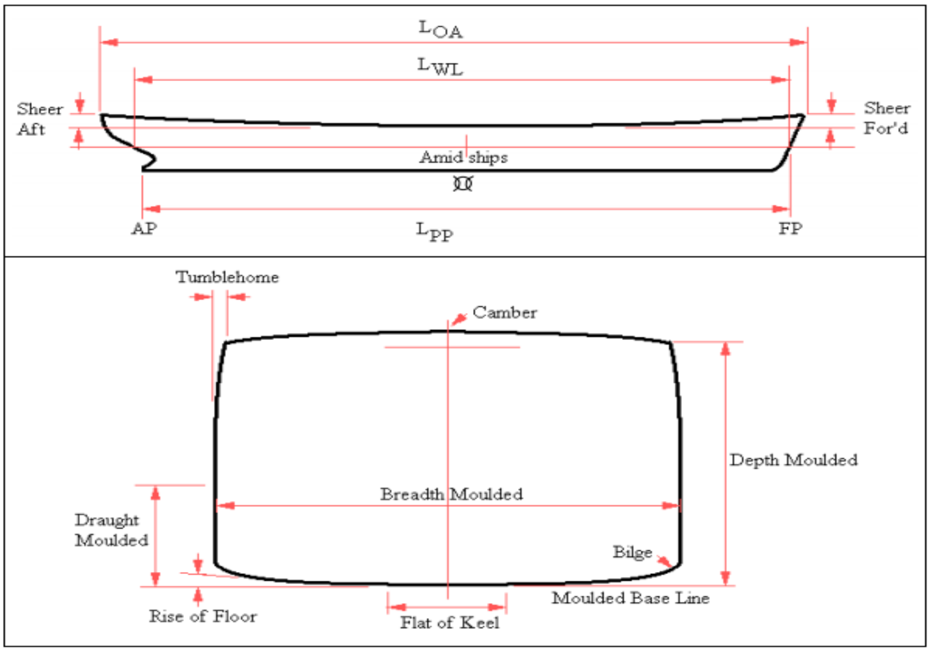

Fig 3.1 Ship Principal Dimension

3.2 The Table 3.1 below illustrate the offset table of an offshore patrol boat (Boat Hull

S/N	Length	Flat Keel	WL 0.5	WL 1	WL 2	WL 3	WL 4	WL main Deck 4.7	WL 5	WL 6	WL 7	WL 8
- 0.25	-1525					2925	5303	5307	-	-	-	-
(AP) 0	0					3791	5725	5728	-	-	-	-
0.5	3050	400			1176	4955	5749	5750	-	-	-	-
1	6100	400			2704	5487	5749	5750	-	-	-	-
1.5	9150	400		789	4108	5658	5750	5750	-	-	-	-
2	12200	400		2113	4972	5713	5750	5750	-	-	-	-
2.5	15250	400	1615	3423	5408	5735	5750	5750	-	-	-	-
3	18300	400	2958	4539	5602	5743	5750	5750	-	-	-	-
4	24400	400	4657	5364	5708	5748	5750	5750	-	-	-	-
5	30500	400	4884	5442	5717	5749	5750	5750	5750	5750	5750	-
6	36600	400	4647	5307	5671	5730	5743	5749	5749	5749	5750	5750
7	42700	400	3716	4685	5216	5407	5519	5580	5598	5654	5702	5745
7.5	45750	400	3039	4166	4847	5116	5283	5367	5397	5518	5490	5657
8	48800	400	2304	3487	4338	4700	4929	5056	5101	5232	5349	5459
8.5	51850	275	1584	2588	3581	4075	4396	4582	4650	4853	5022	5170
9	54900		848	1619	2607	3211	3642	3898	3996	4284	4519	4721
9.25	56425		438	1054	2021	2667	3139	3432	3550	3897	4178	4410
9.5	57950		12	472	1336	2019	2536	2865	3002	3416	3760	4047
9.75	59475				426	1188	1793	2167	2318	2795	3212	3678
(FP)10	61000						722	1255	1441	1993	2474	2910
10.25	62525									776	1470	2019

Geometry)

Table 3.1 The Offset Table for an OffshorePatrol Boat(Half Breath in mm)

3.2.1 The Fig 3.2 below is the body plan of the offshore patrol boat which was model inMaxsurf software from the offset table at the different stations (Transverse sections) and Fig 3.3 below also illustrate the half breath which was model at different water line (vertical sections)

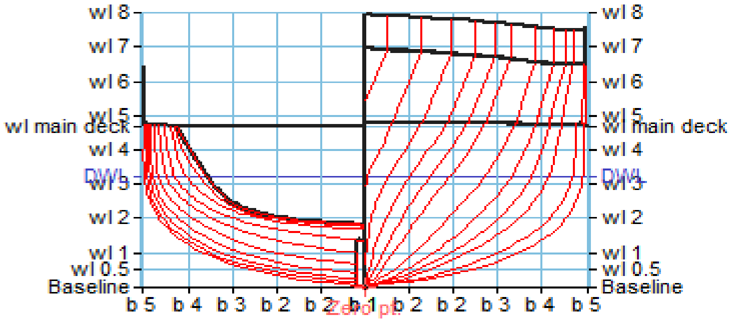

Fig 3.2 Body Plan of an OffshorePatrol Boat

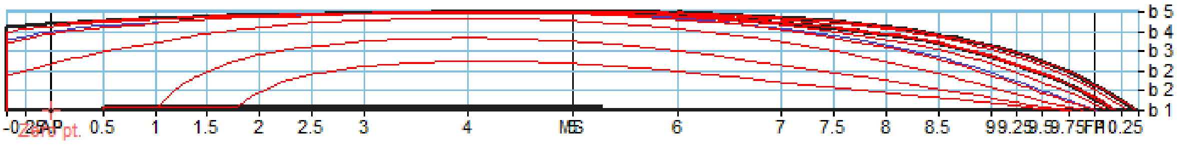

Fig 3.3 Half Breath of anOffshorePatrol Boat

The Table 3.2 below illustrate the offset table of anoffshorepatrol boat continue from Table 1 above (Boat Hull Geometry)

Table 3.2 The Offset Table for an OffshorePatrol Boat (Buttock Height in mm)

S/N	Length	Main Deck crt	Main deck side	BL 0.5	BL 1	BL 2	BL 3	BL 4	BL 5
- 0.25	-1525	4775	4700	2468	2598	2822	3015	5364	3622
(AP) 0	0	4775	4700	2239	2381	2623	2827	3061	3336
0.5	3050	4775	4700	1782	1946	2223	2455	2701	3017
1	6100	4775	4700	1382	1508	1816	2077	2345	2696
1.5	9150	4775	4700	900	1072	1385	1630	1956	2362
2	12200	4775	4700	525	673	967	1263	1529	2017
2.5	15250	4775	4700	234	351	598	874	1185	1643
3	18300	4775	4700	61	129	291	511	796	1253
4	24400	4775	4700	0	3	28	115	294	677
5	30500	4775	4700	0	0	6	47	201	567
6	36600	4775	4700	4	20	57	119	283	705
7	42700	4775	4700	12	70	186	326	608	1415
7.5	45750	4775	4700	18	105	279	492	890	2507
8	48800	4775	4700	26	161	413	738	1086	4582
8.5	51850	4775	4700	78	267	685	1313	2813	6864
9	54900	4775	4700	301	589	1329	2586	5011	
9.25	56425	4775	4700	553	955	1974	5685	6342	
9.5	57950	4775	4700	1030	1597	2964	4995	7824	
9.75	59475	4775	4700	2096	2748	4381	6436		
(FP)10	61000		4700	3730	5099	6014			
10.25	62525			5696	6285	7965			

3.2.2 The Fig 3.3 below is the sheer profile of an offshore patrol boat which was model in maxsurf software from the offset table at the different buttock lines (longitudinal sections)

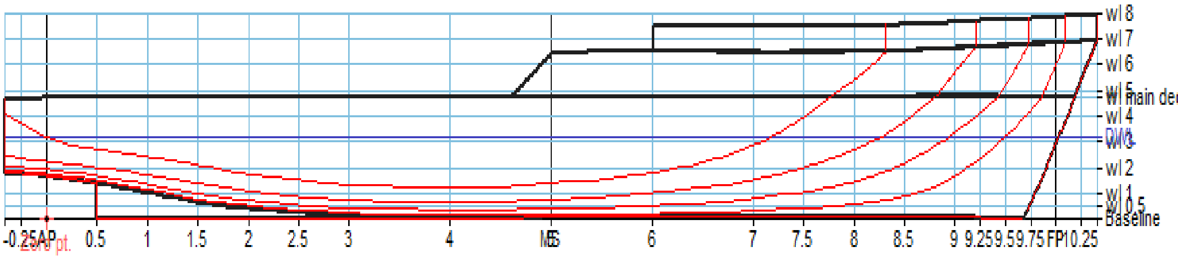

Fig 3.4 The Sheer Profile for an OffshorePatrol Boat

3.2.3 The Fig 3.4 below is the bare hull three-dimension curvature of theoffshore patrol boat which was model in Maxsurf software from the offset table at the different buttock lines (longitudinal section), the different stations (Transverse section) and different water line (vertical section).

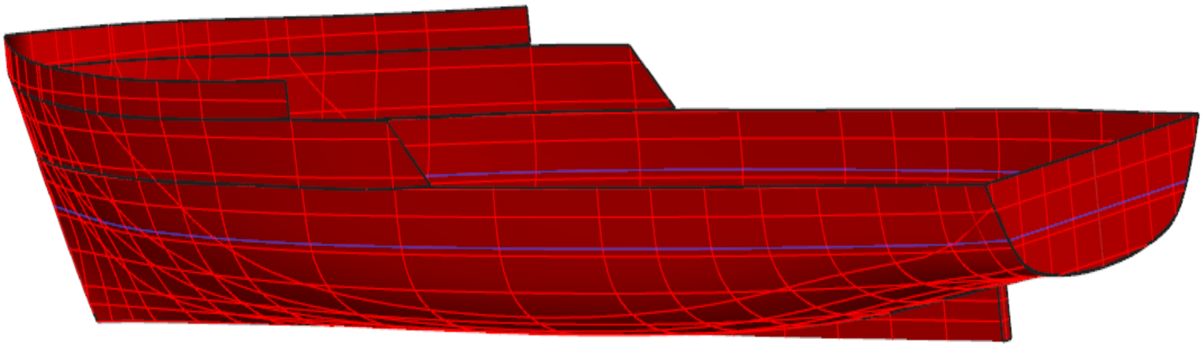

Fig 3,4 The Bare Hull for anOffshorePatrol Boat

3.2.4 The Table 3.3 below is the values estimated to plot the Bonjean curves which was obtained using Simpson 5, 8 minus 1 rule by vertical integration from the offset table above.

Table 3.3 Bonjean Curves Values (Sectional Curves Areas)

S/N	Length (m)	Flat Keel	WL 1 (m^2)	WL 2 (m^2)	WL 3 (m^2)	WL 4 (m^2)	WL main Deck 4.7 (m^2)	WL 5 (m^2)	WL 6 (m^2)	WL 7 (m^2)	WL 8 (m^2)
- 0.25	-1.525		-	-	3.0162	11.6399	15.7979				
(AP) 0	0		-	-	4.1005	13.9383	22.6240				
0.5	3.050		-	0.7422	7.3707	18.2069	26.9772				
1	6.100		-	2.6908	11.3020	22.5748	31.2991				
1.5	9.150		0.3673	5.5591	15.5181	26.9914	35.7122				
2	12.200		1.9886	9.4766	20.2789	31.7481	40.4689				
2.5	15.250		3.9960	13.1033	24.2983	35.7858	44.5066				
3	18.300	-	5.4517	15.7464	27.1137	38.6079	47.3287				
4	24.400	-	6.5340	17.6367	29.1190	40.6173	49.3381				
5	30.500	-	6.6365	17.8360	29.3071	40.8063	49.5271	61.0271	72.5271	84.9854	
6	36.600	-	6.0464	17.4928	28.9015	40.3767	49.0925	60.5855	72.0833	83.5825	96.0408
7	42.700	-	5.7110	15.6687	26.3049	37.2394	45.6668	56.7876	68.0409	79.3977	91.8094
7.5	45.750	-	5.0801	14.1618	24.1418	34.5546	42.6455	53.2244	64.1640	75.1395	87.2572
8	48.800	-	4.2597	12.1512	21.2114	30.7878	38.3820	48.4188	58.7541	69.3363	81.0725
8.5	51.850	-	3.1870	9.4392	17.1240	25.6175	32.4584	41.5129	51.0216	60.9001	71.4146
9	54.900		1.7240	6.0140	11.8608	18.7430	24.5056	32.1546	40.4434	49.2990	59.3134
9.25	56/425		1.0685	2.6328	7.3498	13.1856	18.2199	24.9196	32.3776	40.4608	49.8225
9.5	57/950		0.4067	2.2449	5.6276	10.2139	14.3672	19.9139	26.3436	33.5291	42.0584
9.75	59/475			0.3700	2.0102	5.0297	8.0982	12.0553	17.1783	20.7631	28.3438
(FP)10	61/000					0.3925	1.9850	4.1758	7.6216	12.0961	18.0378
10.25	62/525								0.7897	3.3987	7.3157

Table 3.4 Calculation for finding sectional curves areas (Bonjean curves value) by vertical integrationat station 5 (30.5m aft)

$$A = \frac{s}{12}(5y_0 + 8y_1 - y_2) \qquad (1)$$

Height above baseline, m	Half breath, m	Multiplier for area	Product
0	0.400	5	2.000
1	5.442	8	43.536
2	5.717	-1	-5.717
			Σ_1= 39.819
1	5.442	5	27.210

2	5.717	8	45.736
3	5.749	-1	-5.749
			Σ_2= 67.197

Values for 1m draft at station 5

$A = {}^{s}/_{12} \times \Sigma_1 \times 2 = {}^{1}/_{12} \times 39.819 \times 2 = 6.635\ m^2$ (2)

Values for 2m draft at station 5

$A = {}^{s}/_{12} \times \Sigma_2 \times 2 = {}^{1}/_{12} \times 67.197 \times 2 = 11.1995\ m^2$ (3)

Added area, δA (1m to 2m) about baseline = 6.635 + 11.1995= 17.836m^2

3.2.5The Fig 3.5 below is the Bonjean curves of an offshore patrol boat which was plotted in Maxsurf software, it is curves of sectional areas at transverse section through the boat such as body plan, stations from the baseline up to the waterline and was obtained from Table 3.3 above and will be useful in calculating the volume displaced and longitudinal center of buoyancy (LCF) most especially on trim vessel by drawing a straight line across the contact profile of the vessel.

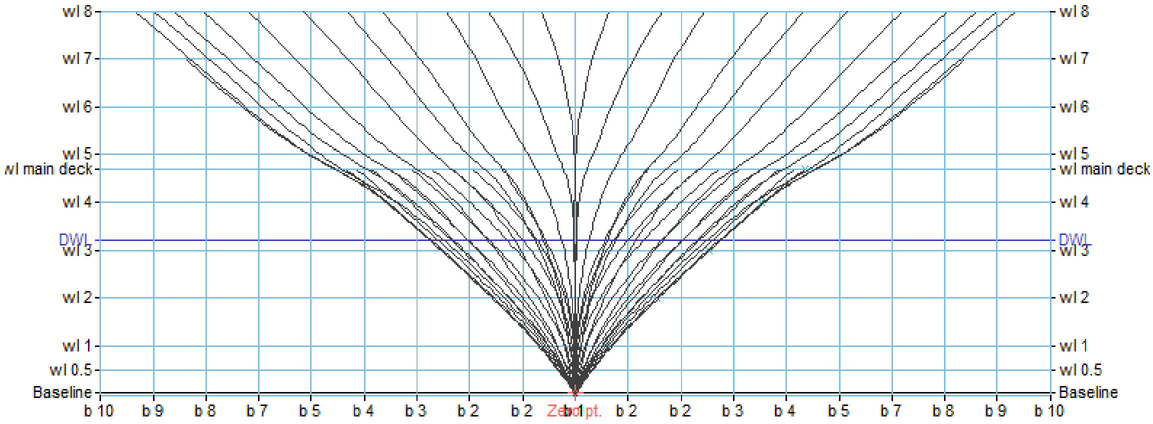

Fig 3.5 Bonjean Curve

3.3 The Table 3.3 below illustrate the calculation of displacement and longitudinal center of buoyancy at 4.7m waterline, were values was obtained from Bonjean curves in Fig 3.5 above.

Table3.3 Calculation forDisplacement and Longitudinal Center of Buoyancy at 4.7m Waterline (Main Deck)

1	2	3	4	5	6	7
S/N	**Length m**	**Area (m^2)**	**S.M**	**Product (3) and (4)**	**Lever (m)**	**Product (5) and (6)**
- 0.25	-1.525	15.7979	0.375	5.9242	5.25	31.1021
(AP) 0	0	22.6240	0.875	19.7960	5	98.98
0.5	3.050	26.9772	2	53.9544	4.5	242.7948
1	6.100	31.2991	1	31.2991	4	125.1964
1.5	9.150	35.7122	2	71.4244	3.5	249.9854
2	12.200	40.4689	1	40.4649	3	121.4067
2.5	15.250	44.5066	2	89.0132	2.5	222.533
3	18.300	47.3287	1.5	70.9931	2	141.9862
4	24.400	49.3381	4	197.3524	1	197.3524
5	30.500	49.5271	2	99.0542	0	0
6	36.600	49.0925	4	196.118	- 1	-196118
7	42.700	45.6668	1.5	68.5002	- 2	-137.0004
7.5	45.750	42.6455	2	85.2910	- 2.5	-213.2275
8	48.800	38.3820	1	38.3820	- 3	-115.1460
8.5	51.850	32.4584	2	64.9168	- 3.5	-227.2088
9	54.900	24.5056	0.75	18.3867	- 4	-73.5468
9.25	56/425	18.2199	1	18.2199	- 4.25	-77.4346
9.5	57/950	14.3672	0.5	7.1836	- 4.5	-32.3262
9.75	59/475	8.0982	1	8.0982	- 4.75	-38.4665
(FP)10	61/000	1.9850	0.625	1.2406	- 5	-6.203
10.25	62/525		0.375	-	-5.25	-
				Σ_a = 1,204.0036		**Σ_b = 314.6572**

- Station Spacing, $s = {}^{l}/_{10}$ (4)

- Volume displace, $\nabla = \Sigma_a \times {}^{2}/_{3}$ (5)
- Displacement, $\Delta = \nabla \times \rho$ (6)
- Longitudinal center of buoyancy. $LCB = {}^{\Sigma_b}/_{\Sigma_a} \times s$ (7)

3.4 Method for Calculating Areas

3.4.1 Trapezoidal method

A curve can be represented by set of trapezoids at different draught; the area under the curves can be calculated

Area = ½ x Σ(y) x spacing **o**r ½ x sum of parallel side x height

For curve having eleven trapezoid with half breath of y_0, y_1, y_2, y_3, y_4.……y_{10} and equalspacing

Area (m²) = $\frac{1}{2}(y_0 + y_1)\, s + \frac{1}{2}(y_1 + y_2)\, s + \ldots\ldots \frac{1}{2}(y_9 + y_{10})\, s$ (8)

Area (m²) = $\frac{1}{2}(y_0 + 2y_1 + 2y_2 + 2y_3 + \ldots\ldots 2y_{(n-1)} + y_n)\, s$ (9)

Cross sectional area = $\int_o^h y(x)dx$ (10)

y = half breath

3.4.2 Simpson's First Rule

The area under the curves can be calculated using Simpson's first rule

Area = $\Sigma(y) \times {}^{1}/_{3}$ x spacing (11)

For curve having eleven segments with half breath of y_0, y_1, y_2, y_3, y_4. …. y_{10} and equal spacing

Area (m²) = ${}^{1}/_{3}(y_0 + 4y_1 + y_2)\, s + {}^{1}/_{3}(y_2 + y_3 + y_4)\, s + \ldots\ldots {}^{1}/_{3}(y_8 + y_9 + y_{10})\, s$ (12)

Area (m²) = ${}^{1}/_{3}(y_0 + 4y_1 + 2y_2 + 4y_3 \ldots\ldots\ldots\ldots + 4y_{(n-1)} + y_n)\, s$ (13)

3.4.3 The volume displacement and area curves are extended beyond stations 0 and 10 to extremities as shown by Table 3.3 above and Table 3.4 below which was a combination of Trapezoidal Rule and Simpson's First Rule and was proportioned accordingly to Simpson's Multiplier.

Converting Trapezoidal Rule to Simpson's proportioned

${}^{1}/_{3} \times {}^{1}/_{2}((y_0 \times 3) + (y_1 \times 3))\, s = {}^{1}/_{3}(y_0 {}^{3}/_{2}) + (y_1 {}^{3}/_{2}) s$

Thus, at Station -${}^{1}/_{4}$, Simpson's Multiplier (SM) = ${}^{3}/_{2} \times {}^{1}/_{4} = {}^{3}/_{8}$ or 0.375

At Station 0, SM = ${}^{3}/_{8} + {}^{1}/_{2} = {}^{7}/_{8}$ or 0.875

At Station 10, SM = ${}^{3}/_{8} + {}^{1}/_{4} = {}^{5}/_{8}$ or 0.625

At Station $10{}^{1}/_{4}$, SM = ${}^{3}/_{8}$ or 0.375

3.4 The Table 3.4 below illustrate the calculation of waterplane characteristics at 4.7m waterline, were values was obtained from Bonjean curves in Fig 3.5 above. were values was obtained from the offset table in Table 3.1 above

Table 3.4 Calculation of Waterplane Characteristics at 4.7m Waterline (Main Deck)

1	2	3	4	5	6	7	8	9	10	11
S/N	**Length (m)**	**Half Breath (m)**	**S.M**	**Product 3 and 4**	**Lever (m)**	**Product 5 and 6**	**(Lever)² (m²)**	**Product 5 and 8**	**(Half Breath)³(2 ³) (m³)**	**Product 4 and 10 (m³)**
- 0.25	-1.525	5.307	0.375	1.990	5.25	10.448	27.5625	54.8494	149.4677	56.0504
(AP) 0	0	5.728	0.875	5.012	5	25.060	25.0000	125.300	187.9356	164.4437

0.5	3.050	5.750	2	11.500	4.5	51.750	20.2500	232.8750	190.1094	380.2188
1	6.100	5.750	1	5.750	4	23.000	16.0000	92.0000	190.1094	190.1094
1.5	9.150	5.750	2	11.500	3.5	40.250	12.2500	140.8750	190.1094	380.2188
2	12.200	5.750	1	5.750	3	17.250	9.0000	51.7500	190.1094	190.1094
2.5	15.250	5.750	2	11.500	2.5	28.750	6.2500	71.8750	190.1094	380.2188
3	18.300	5.750	1.5	8.625	2	17.250	4.0000	36.5000	190.1094	285.1641
4	24.400	5.750	4	23.000	1	23.000	1.0000	23.0000	190.1094	760.4376
5	30.500	5.750	2	11.500	0	0	0	0	190.1094	380.2188
6	36.600	5.749	4	22.996	- 1	-22.996	1.0000	22.9960	190.0102	760.0408
7	42.700	5.580	1.5	8.370	- 2	-16.740	4.0000	33.4800	173.7411	260.6117
7.5	45.750	5.367	2	10.734	- 2.5	-26.835	6.2500	67.0875	154.5948	309.1896
8	48.800	5.056	1	5.056	- 3	-15.168	9.0000	45.5040	129.2472	129.2772
8.5	51.850	4.582	2	9.164	- 3.5	-32.074	12.2500	112.2590	96.1978	192.3956
9	54.900	3.898	0.75	2.924	- 4	-11.696	16.0000	46.7840	59.2278	44.4209
9.25	56/425	3.432	1	3.432	- 4.25	-14.586	18.06625	61.9905	40.4242	40.4242
9.5	57/950	2.865	0.5	1.433	- 4.5	-6.449	20.2500	29.0183	23.5166	24.0166
9.75	59/475	2.167	1	2.167	- 4.75	-10.293	22.5625	48.8929	10.1760	10.1760
(FP)10	61/000	1.255	0.625	0.784	- 5	-3.922	25.0000	19.600	1.9767	1.2354
10.25	62/525	-	0.375		-5.25	-	27.5625	-	-	-
				Σ_1 = 163.187		**Σ_2 = 75.979**		**Σ_3 = 1314.656**		**Σ_4 = 4938.948**

- Waterplane Area, $A_{wp} = \Sigma_1 \times {}^{2}/_{3} \times s$ (14)
- Tonnes per CM immersion (TPC) = $^{Awp\ \times \rho}/_{100}$ (15)
- Longitudinal center of flotation, LCF = $^{\Sigma_2}/_{\Sigma_1} \times s$ (16)
- Longitudinal moment of inertia about station 5, $I_{L,5} = \Sigma_3 \times {}^{2}/_{3} \times s^3$ (17)
- Longitudinal moment of inertia about LCF, $I_L = I_{L,5} - A_{wp} \times (LCF)^2$ (18)
- Transverse moment of inertia, $I_T = \Sigma_4 \times {}^{2}/_{g} \times s$ (19)
- Block coefficient, $C_B = {}^{\nabla}/_{L_{WL}\ \times b\ \times\ T_M}$ (20)
- Midship coefficient, $C_m = {}^{A_m}/_{b\ \times\ T_M}$ (21)
- Prismatic coefficient, $C_P = {}^{\nabla}/_{A_{WP}\ \times\ T_M}$ (22)
- Water plane coefficient, $C_{WP} = {}^{A_{WP}}/_{L_{WL}\ \times\ b}$ (23)
- Buoyancy above keel, KB = T ($^{A_{WP}}/_{A_{WP}\ +\ {}^{\nabla}/_{T}}$ (24)
- Longitudinal meta center above buoyancy, $BM_L = {}^{I_L}/_{\nabla}$ (25)
- Transverse meta center above buoyancy, $BM_T = {}^{I_T}/_{\nabla}$ (26)
- Transverse meta center above keel, $KM_T = KB + BM_T$ (27)
- Longitudinal meta center above keel, $KM_L = KB + BM_L$ (28)
- Transverse meta center above gravity, $GM_T = KM_T$at preliminary design (29)
- Longitudinal meta center above gravity, $GM_L = KM_L$ at preliminary design (30)
- Moment causing 1cm trim, MT_L cm = $^{\Delta\ \times GM_L}/_{100L}$ (31)

(32)

IV. Result and Discussion

4.1 Result Table 4.1 below illustrate the condense summary result of an offshore patrol boat hydrostatics properties which was obtained from Maxsurf modeling software

Table 4.1 Condense Summary Hydrostatics Propertiesfor Offshore Patrol Boat

S/n	Measurement	WL 0.5	WL 1	WL 2	WL 3	WL 3.2 Draft	WL 4	WL 4.7 main Deck	WL 5	Units
1	Displacement	97.31	282.3	777.3	1375	1506	2040	2515	2625	Tonnes
2	Volume (displaced)	94.939	275.446	758.382	1341.645	1469.034	1990.292	2453.935	2561.404	m^3
3	Draft Amidships	0.490	0.990	1.990	2.990	3.190	3.990	4.690	4.990	M
4	Immersed depth	0.500	1.000	2.000	3.000	3.200	4.000	4.700	5.000	M
5	Immersed depth of station with max area	0.490	0.990	1.990	2.990	3.190	3.990	4.690	4.990	M
6	Immersed depth Amidships	0.490	0.990	1.990	2.990	3.190	3.990	4.690	4.990	M
7	WL Length	48.589	51.662	60.582	63.517	63.701	64.430	65.038	33.455	M
8	Beam max extents on WL	9.815	10.947	11.407	11.496	11.506	11.502	11.501	11.500	M
9	Beam max on WL	9.815	10.947	11.407	11.496	11.506	11.502	11.501	11.500	M
10	Beam extents on WL of station with max area	9.799	10.887	11.407	11.482	11.488	11.499	11.500	11.500	M
11	Beam on WL of station with max area	9.799	10.887	11.407	11.482	11.488	11.499	11.500	11.500	M
12	Wetted Area	302.418	433.632	612.669	798.018	833.690	949.699	1050.619	1074.557	m^2
13	Max sect. Area	3.769	8.998	20.229	31.681	33.978	43.174	51.224	54.674	m^2
14	Waterpl. Area	296.056	414.299	536.771	629.171	642.396	657.792	666.812	309.819	m^2
15	Prismatic coeff. (Cp)	0.518	0.593	0.619	0.667	0.679	0.715	0.737	1.400	
16	Block coeff. (Cb)	0.398	0.487	0.549	0.613	0.626	0.671	0.698	1.332	
17	Max Sect. area coeff. (Cm)	0.785	0.835	0.891	0.923	0.927	0.941	0.950	0.953	
18	Waterpl. area coeff. (Cwp)	0.621	0.733	0.777	0.862	0.876	0.888	0.891	0.805	
19	LCB length	28.272	28.949	29.096	28.553	28.382	27.915	27.742	28.281	(+ve fwd) m
20	LCF length	29.110	29.386	28.794	26.769	26.486	26.797	27.186	43.439	(+ve fwd) m
21	LCB %	58.186	56.035	48.027	44.954	44.555	43.326	42.655	84.535	(+ve fwd) % Lwl
22	LCF %	59.911	56.882	47.529	42.145	41.578	41.591	41.801	129.843	(+ve fwd) % Lwl
23	VCB	0.297	0.596	1.178	1.754	1.870	2.321	2.703	2.792	M
24	KB	0.297	0.596	1.178	1.754	1.870	2.321	2.703	2.792	M
25	KG fluid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	M
26	BMt	14.926	10.656	6.387	4.476	4.238	3.255	2.686	1.077	M
27	BML	395.424	237.777	147.539	127.067	122.759	96.456	81.172	9.024	M
28	GMt corrected	15.222	11.252	7.565	6.230	6.108	5.576	5.389	3.869	M
29	GML	395.720	238.373	148.717	128.821	124.629	98.777	83.874	11.816	M
30	KMt	15.222	11.252	7.565	6.230	6.108	5.576	5.389	3.869	M
31	KML	395.720	238.373	148.717	128.821	124.629	98.777	83.874	11.816	M
32	Immersion (TPc)	3.035	4.247	5.502	6.449	6.585	6.742	6.835	3.176	tonne/cm
33	MTc	6.313	11.033	18.951	29.042	30.764	33.034	34.585	5.086	tonne.m
34	RM at 1deg = GMt.Disp.sin (1)	25.853	55.444	102.635	149.532	160.523	198.538	236.544	177.278	tonne.m
35	Length: Beam ratio	4.950	4.719	5.311	5.525	5.537	5.602	5.655	2.909	
36	Beam: Draft	19.635	10.948	5.704	3.832	3.596	2.876	2.447	2.300	

	ratio									
37	Length: Vol^0.333 ratio	10.651	7.940	6.643	5.759	5.604	5.122	4.822	2.445	
38	Precision	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	67 stations

4.2 Result Table 4.2 below illustrate the validation summary result of an offshore patrol boat hydrostatic properties obtained at 4.7 m waterline between Maxsurf modeling software and result obtained from mathematical modeling, also the deviation from Maxsurf modeling result

S/N	**Measurement**	**Result from Masurf at WL 4.7 main Deck**	**Result from Mathematical model at WL 4.7 main Deck**	**% deviation from Maxsurf Result**	**Units**
1	Displacement	2515	2510	0.23	T
2	Volume (displaced)	2453.935	2448.3442	0.24	m^3
3	Draft Amidships	4.690	-	-	M
4	Immersed depth	4.700	4.700	-	M
5	Immersed depth of station with max area	4.690	-	-	M
6	Immersed depth Amidships	4.690	-	-	M
7	WL Length	65.038	65.038	-	M
8	Beam max extents on WL	11.501	-	-	M
9	Beam max on WL	11.501	-	-	M
10	Beam extents on WL of station with max area	11.500	11.500	-	M
11	Beam on WL of station with max area	11.500	11.500	-	M
12	Wetted Area	1050.619		-	m^2
13	Max sect. area	51.224	49.5271	3.32	m^2
14	Waterpl. Area	666.812	663.627	0.48	m^2
15	Prismatic coeff. (Cp)	0.737	0.785	-6.50	
16	Block coeff. (Cb)	0.698	0.696	0.23	
17	Max Sect. area coeff. (Cm)	0.950	0.920	3.16	
18	Waterpl. area coeff. (Cwp)	0.891	0.900	-1.01	
19	LCB length	27.742	28.909	-4.09	(+ve fwd) m
20	LCF length	27.186	27.659	-1.82	(+ve fwd) m
21	LCB %	42.655	43.762	-2.60	(+ve fwd) % Lwl
22	LCF %	41.801	41.870	-0.17	(+ve fwd) % Lwl
23	VCB	2.703	2.633	2.60	M
24	KB	2.703	2.633	2.60	M
25	KG fluid	0.000	0.000	-	M
26	BMt	2.686	2.735	1.83	M
27	BML	81.172	79.0727	2.59	M
28	GMt corrected	5.389	5.368	0.39	M
29	GML	83.874	81.706	2.59	M
30	KMt	5.389	5.368	0.39	M
31	KML	83.874	81.706	2.59	M
32	Immersion (TPc)	6.835	6.802	0.48	tonne/cm
33	MTc	34.585	31.524	8.85	tonne.m
34	RM at 1deg = GMt.Disp.sin(1)	236.544	-	-	tonne.m
35	LengthBeam ratio	5.655	5.655	-	
36	Beam:Draft ratio	2.447	2.447	-	
37	Length:Vol^0.333 ratio	4.822	4.822	-	
38	Precision	67 stations	21 stations	68.66	

Table 4.2 Validation of Result using Maxsurf Modeling Software

The result indicated that the higher the precision (more stations), the best fit curves is obtained for ship hull hydrostatics properties in preliminary design.

4.3 Result Fig 4.1 below illustrate the graphical summary result of a sectional areas curve at 4.7m waterline across the stations of an offshore patrol

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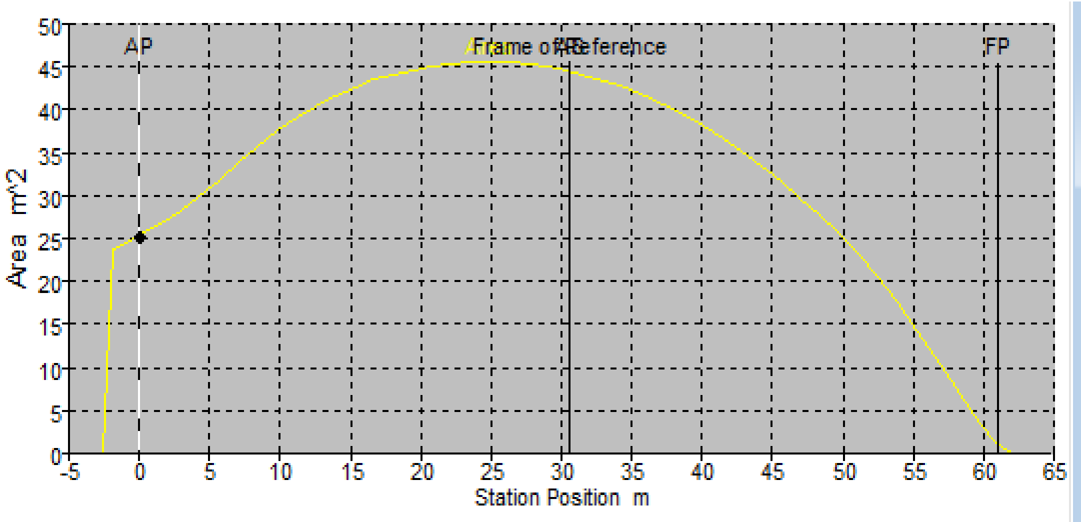

Fig 4.1 Graph of Section AreasCurve

V. Conclusion

5.1 Ship hydrostatics properties estimation is very important in the early stage of design analysis of a ship to enable the Naval Architects achieve design properties of the ship hull requirements or use ship hydrostatics properties to modify for similar ship of the same range. Also enable the Naval Architects to have a fit curves ship hull shape to move on water with least resistance, low fuel consumption and design speed. The result obtained in this paper express correlation satisfaction with statistical proof test for an offshore patrol boat. Further,the result obtained from Mathematical Model was validated with Maxsurf Software were boat result agrees, observation indicated that the higher the precision(more stations), accurate the result for best fit curves of ship hullshape is obtained for ship hydrostatics preliminary design.

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