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STUDY REGARDING THE INFLUENCE OF SHIP HULL FORMS ON THE PROPELLER DESIGN FOR A CONTAINER SHIP

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ABSTRACT

The paper presents the results of the second stage of a study regarding the ship hull forms influence on the propulsive performances for an imposed capacity containership. In the first stage, starting from the dimensions and the forms of a given containership, other ten ship hulls have been generated and the hydrodynamic ships' resistance have been computed. In the second stage, for two of the generated ship hull forms having the lowest resistance, the propellers have been designed, encountering problems with the placement of the optimal propeller in the after end of the ship. This focused the present study on the changing the dimensions and shapes of the aft end for these two ships, in an attempt to ensure the installation of a propeller with an optimal diameter from propulsive efficiency point of view, as large is possible.

Keywords: portcontainer, propulsion performances, propeller design, propeller clearance

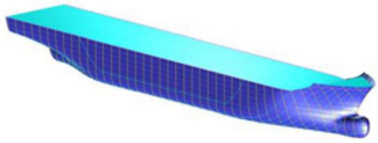
1. INTRODUCTION

The work done in the second stage of a study regarding the ship hull forms influence on the propulsive performances for an imposed capacity containership are presented in this paper. In the first step, based on the main dimensions and shapes of an imposed capacity containership, ten ships hulls have been generated with DELFTship calculation program, the hydrodynamic ships' resistance have been computed and the results have been presented in a previous paper [1].

In the second step, two of the new generated ship hull forms having the lowest hydrodynamic resistance have been selected to continue the investigations, respectively to design the propulsion system, ensuring the best performances in terms of propulsion efficiency. Different main engines have been selected and the propellers have been designed, encountering problems with the placement of the optimal propeller in the stern area. This focused the present study on the changing the dimensions and shapes of the after end for these two ships, in an attempt to ensure the installation of a propeller with an optimal diameter from propulsive efficiency point of view, as large is possible.

In the future third stage, aspects regarding the influence of ships forms on the propulsive performances considering the IMO conditions for reducing greenhouse gases emissions (Energy Efficiency Design Index - EEDI) will be analysed.

All the investigations have been carried out started from an imposed capacity containership (1805 TEU), having the main dimensions and shapes given in Figure 1 [1],[2].



- Length over all.........173,950 [m]
- Floating length.........166,000 [m]
- Beam...................27,300 [m]
- Draught................8,500 [m]

Fig. 1. Main dimensions and shapes for the initially containership [1], [2]

2. SHIP SHAPES INVESTIGATION AND SELECTION

In the first stage, based on the main dimensions and the shapes for the given containership, ten ship hulls have been generated with DELFTship calculation program. For every case, the total hydrodynamic ships' resistance (Rt [kN]) and hull propeller interaction coefficients (w, t – wake and thrust deduction coefficients) have been computed for a ship velocity range around the owner required speed, using the Holtrop Mennen method.

In the second stage, two of the new generated ship hull forms, having the lowest hydrodynamic resistance at 18.7 knots have been selected to continue the study (Ship 2 and Ship 5 - Figure 2 [1]), respectively to chose and design the main components of the propulsion system, ensuring the best performances in terms of propulsion efficiency.

The necessary propulsive power has been calculated for the main engines selection and the propellers have been designed, encountering problems with the placement of the optimal propeller in the after end of the ship. This focused the present study on the changing the dimensions and shapes of the aft end for these two ships, in an attempt to ensure the installation of a propeller with an optimal diameter from propulsive efficiency point of view, as large is possible.

Thus, starting from the ship's hull forms with the best performances in terms of minimum hydrodynamic resistance (Ship 2 and Ship 5), another 6 new ship hulls have been generated, deriving by turn the main dimensions with: 0,5 m on the beam, 0,5 m on the length, 0,5 m on the draught. Due to the main dimensions' derivation, the geometrical characteristics for the new ships have been changed (Figure 3). The 2D shape lines, 3D model-lines and model-surface for the new ships are presented in Figures 4-9.

	1805 T.E.U	Ship 1	Ship 2	Ship 3	Ship 4	Ship 5	Ship 6	Ship 7	Ship 8	Ship 9	Ship 10
Rt [kN]	1385.24231	1463.741	1261.262	1577.545	1689.868	1323.440	1471.827	1552.463	1520.747	1404.986	1466.413
w	0.23604431	0.236	0.235	0.238	0.235	0.234	0.234	0.236	0.322	0.234	0.237

Fig.2. Total ship resistance and w-wake coefficients for the initial generated 10 ship hulls [1]

	Ship 2-original	Ship 5-original	Ship 2-draft+0.5	Ship 5-draft+0.5	Ship 2-beam+0.5	Ship 5-beam+0.5	Ship 2-lenght+0.5	Ship 5-lenght+0.5
Ltotal	171,500	167,494	173,072	168,087	171,950	167,731	172,132	168,087
Lwl	166,015	166,014	166,000	166,000	166,000	166,001	166,500	166,500
B	27,301	27,300	27,300	27,300	27,800	27,800	27,300	27,300
T	8,500	8,500	9,000	9,000	8,500	8,500	8,500	8,500
Awl	4040,700	3934,480	3971,510	3815,250	4086,010	3960,050	4044,990	3938,050
Am	228,093	225,626	241,574	239,060	232,268	229,784	228,076	225,627
Abt	21,716	16,616	19,700	15,428	21,086	16,182	21,400	16,257
At	11,439	2,496	15,124	3,727	11,694	2,541	11,484	2,496
volume	28864,226	28913,904	28906,353	28944,177	28895,429	28921,836	28814,675	28936,865
cb	0,749	0,751	0,709	0,710	0,737	0,737	0,746	0,749
cp	0,762	0,772	0,721	0,729	0,749	0,758	0,759	0,770
H(const)	13,504	13,500	14,001	14,000	13,504	13,500	13,500	13,500

Fig.3. Main geometrical characteristics for the new generated 6 ship hulls

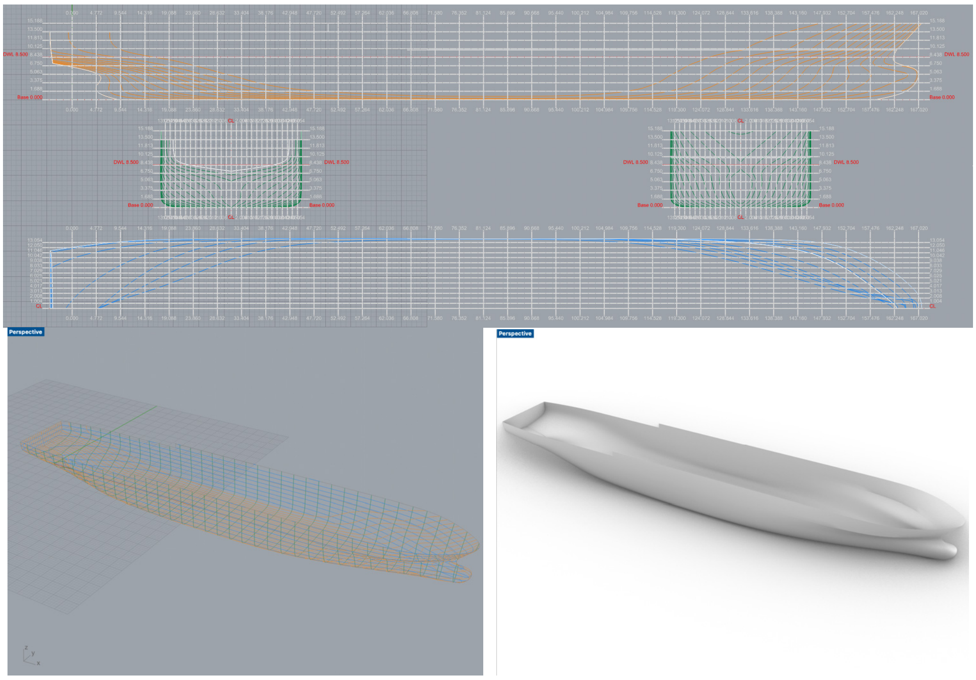


Fig. 4. Ship 2 beam+0.5, 2D shape lines, 3D model-lines and 3D model-surface

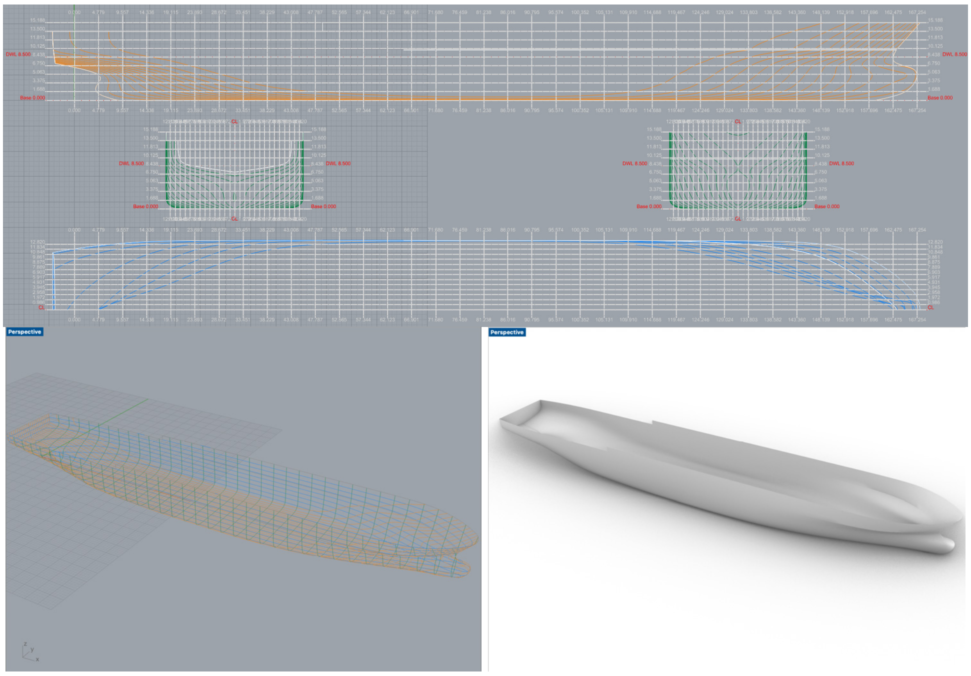


Fig. 5. Ship 2 length+0.5, 2D shape lines, 3D model-lines and 3D model-surface

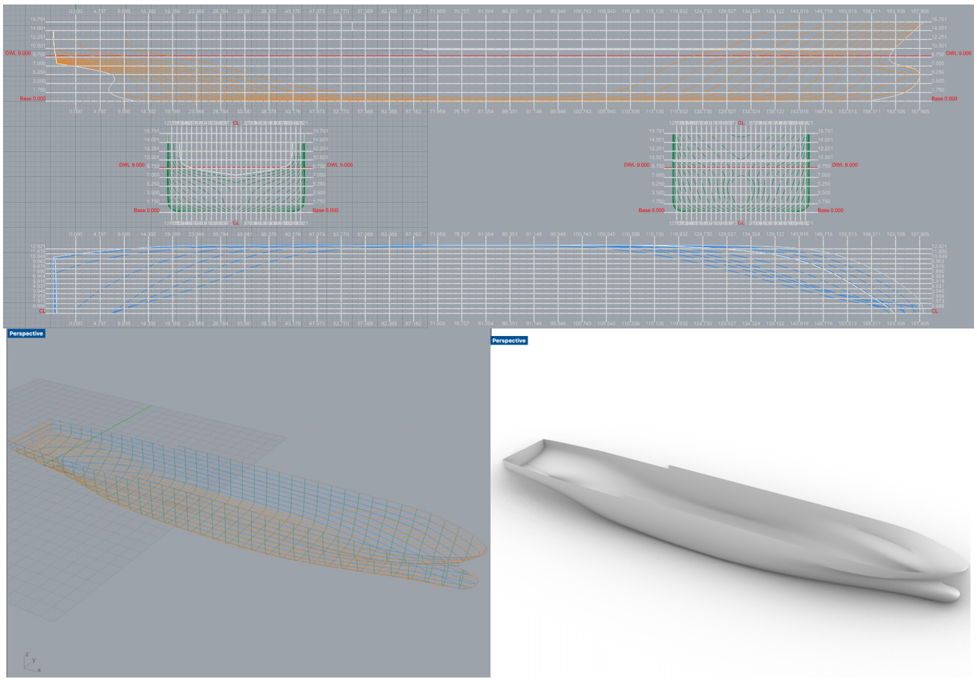


Fig. 6. Ship 2 draught+0.5, 2D shape lines, 3D model-lines and 3D model-surface

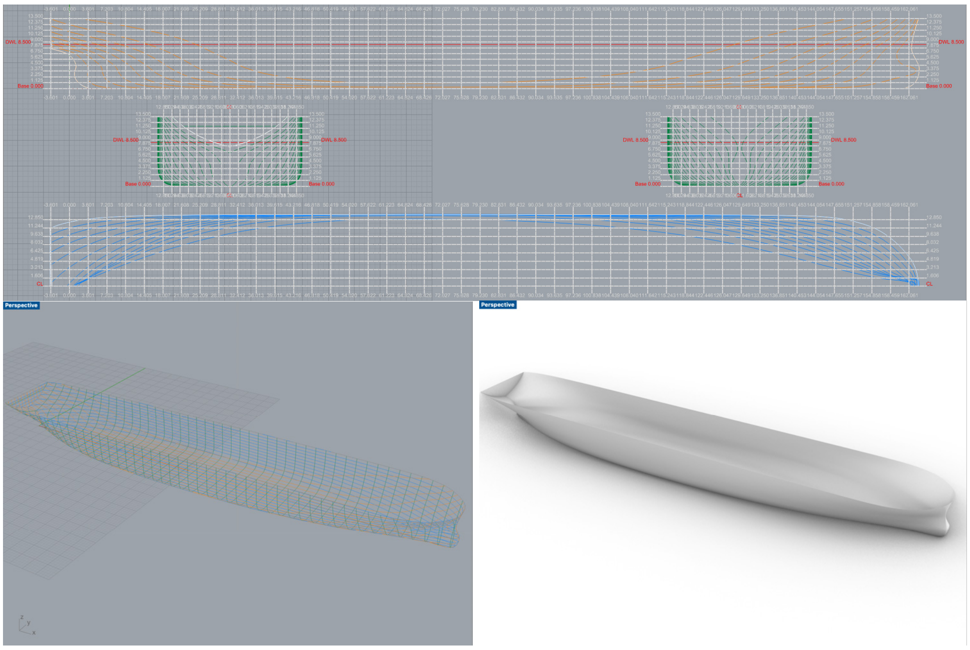


Fig. 7. Ship 5 beam+0.5, 2D shape lines, 3D model-lines and 3D model-surface

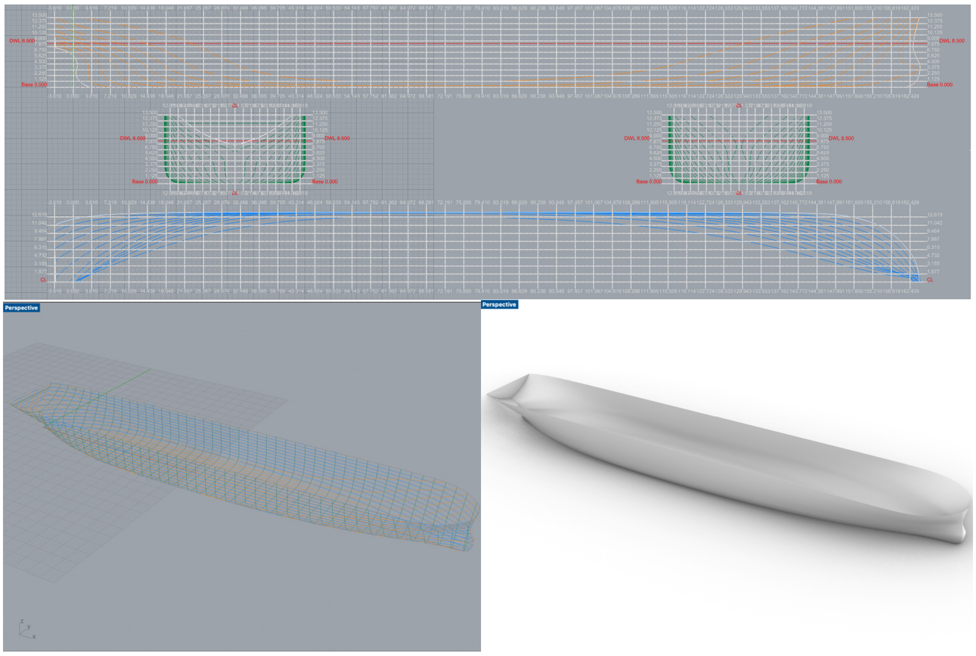


Fig. 8. Ship 5 length+0.5, 2D shape lines, 3D model-lines and 3D model-surface

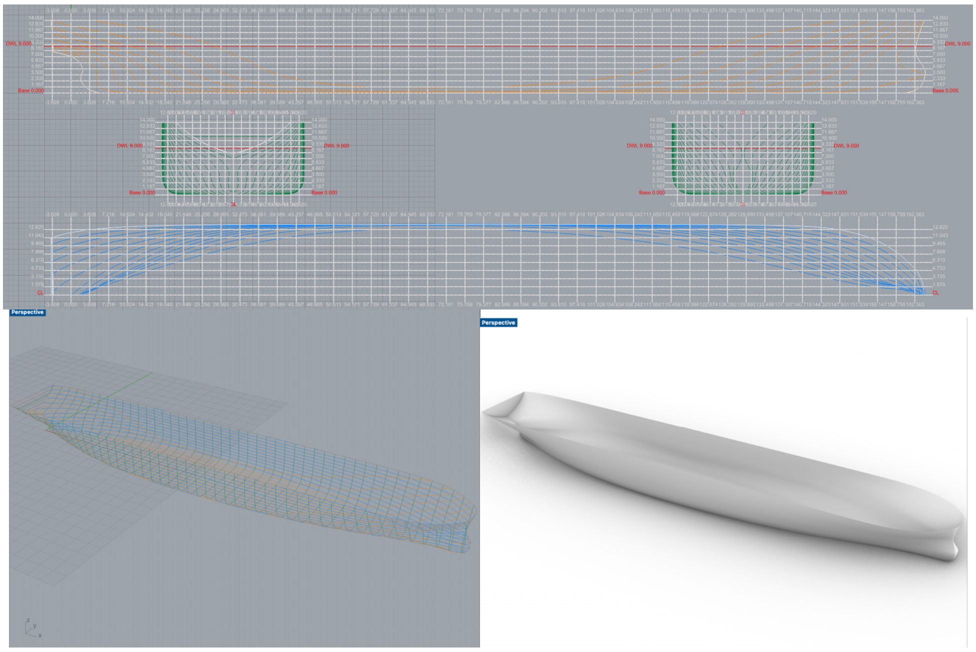
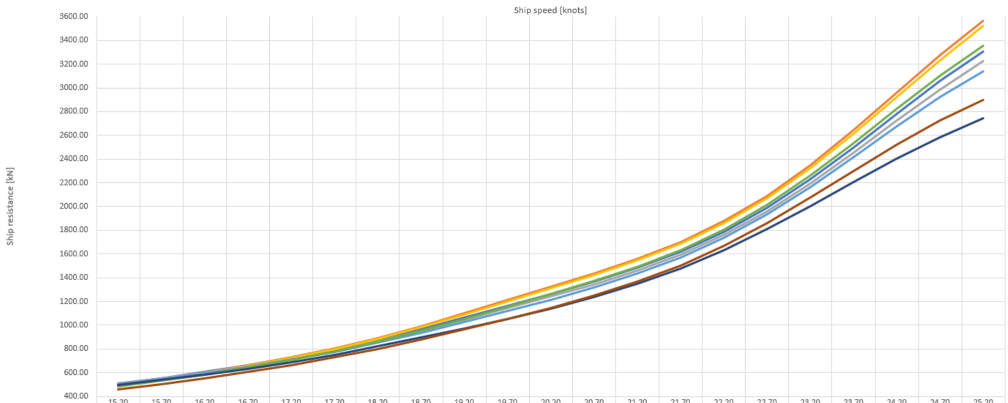


Fig. 9. Ship 5 draught+0.5, 2D shape lines, 3D model-lines and 3D model-surface



	15.20	15.70	16.20	16.70	17.20	17.70	18.20	18.70	19.20	19.70	20.20	20.70	21.20	21.70	22.20	22.70	23.20	23.70	24.20	24.70	25.20
Ship 2-original	505.72	553.01	605.38	662.95	726.04	796.14	875.44	964.63	1061.30	1161.04	1261.26	1367.24	1484.28	1621.90	1789.45	1992.88	2232.31	2500.18	2781.34	3056.13	3305.73
Ship 5-original	493.37	543.72	599.94	662.17	730.54	806.50	892.73	990.79	1098.60	1210.92	1323.44	1437.27	1559.95	1702.88	1877.60	2092.57	2350.28	2644.72	2960.65	3276.02	3567.60
Ship 2-length+0.5	502.54	549.06	600.51	657.01	718.91	787.67	865.32	952.40	1046.55	1143.67	1241.52	1345.18	1460.35	1595.77	1760.18	1959.01	2191.98	2451.45	2722.68	2986.88	3226.41
Ship 5-length+0.5	491.66	541.56	597.25	658.86	726.54	801.68	886.89	983.67	1090.03	1200.92	1312.16	1424.82	1546.22	1687.43	1859.71	2071.31	2324.65	2613.87	2924.15	3233.98	3520.75
Ship 2-beam+0.5	498.36	543.75	593.86	648.82	709.18	776.44	852.32	936.84	1027.45	1120.65	1215.34	1317.42	1432.98	1569.94	1735.83	1934.53	2164.09	2415.51	2673.70	2920.99	3142.25
Ship 5-beam+0.5	482.42	530.30	583.58	642.38	707.11	779.34	861.27	953.53	1053.61	1157.14	1261.72	1370.09	1489.98	1631.51	1804.08	2013.58	2259.82	2534.69	2822.43	3102.88	3357.03
Ship 2-draft+0.5	494.00	536.38	582.74	633.42	689.29	751.47	820.42	895.03	973.36	1054.54	1140.48	1235.89	1346.74	1478.46	1633.91	1811.80	2005.80	2208.25	2405.97	2586.55	2744.25
Ship 5-draft+0.5	459.88	503.37	551.35	604.14	662.60	728.08	801.40	881.60	966.34	1054.00	1145.94	1246.96	1363.84	1503.22	1669.37	1862.27	2076.26	2300.28	2520.23	2722.95	2900.02

Fig.10. Ships resistance for the initial Ship 2, Ship 5 and for new derivated 6 ship hulls

Ship Speed knots	Ship 2-original	Ship 5-original	Ship 2-draft+0.5	Ship 5-draft+0.5	Ship 2-beam+0.5	Ship 5-beam+0.5	Ship 2-lenght+0.5	Ship 5-lenght+0.5
16,700	662,953	662,169	633,423	604,144	648,822	642,383	657,013	658,859
17,700	796,141	806,498	751,474	728,082	776,438	779,342	787,672	801,678
18,700	964,629	990,788	895,034	881,599	936,843	953,528	952,400	983,668
19,700	1161,042	1210,921	1054,539	1054,003	1120,645	1157,136	1143,672	1200,923
20,700	1367,239	1437,269	1235,885	1246,960	1317,418	1370,093	1345,176	1424,825

Fig.11. Total ship resistance for new generated 6 ship hulls at 18.7 knots ship speed

3. RESULTS REGARDING PROPELLER DESIGN

The results regarding the hydrodynamic ship resistance for the new 6 ships hulls generated starting from Ship 2 and Ship 5 have been computed and plotted for a velocities range around the owner required speed (Figures 10,11).

Analysing the ship resistance for the new generated 6 ships shapes (Figures 10,11), two ship hull forms (Ship 2 draft+0.5 and Ship 5 draft+0.5) having the lowest hydrodynamic resistance have been selected to continue the present investigation. Using the ship resistance as initial data, the necessary propulsive power has been computed for main engines selection. The study has been performed for two slow diesel engines with the following characteristics:

- case 1. P_b=19920 kW, n_o =105rpm,
- case 2. P_b=16020 kW, n_o=117 rpm,

where P_b is the brake power and n_o the engine the revolution rate.

For each studied ship hull and for the chosen main engine, the optimal propeller in terms of efficiency point of view has been designed to consume the delivered power and the results have been presented in Figures 12,13. The propellers have been designed for two different design points taking into consideration the sea margin SM=15% and different values for the engine margin EM=0-10% [4] (power using coefficient cu=0.85 and cu=0.75). The results regarding propellers design for Ship 2 draught+0.5 and Ship 5 draught+0.5 for the selected engines are presented in Figures 12,13.

There were still problems with the placement of the propeller with optimal diameter from the efficiency point of view in the stern area. It is known that a higher propeller diameter and a lower revolution rate led to a higher efficiency from the energetic point of view. But from a constructive point of view, the after body hull lines, the draught and the clearance between tip propeller and ship hull have to be taken into account.

	Ship 2			
	Case I	Case II	Case III	Case IV
Pb	16020	16020	19920	19920
n0 [rpm]	117	117	105	105
nc	9	9	9	9
Cu	0,750	0,850	0,850	0,750
D	6,164	6,182	6,890	6,870
n(p) [rpm]	112,964	117,000	105,000	101,378
z	5	5	5	5
Ae/A0	1,050	1,050	1,050	1,050
P/d	0,891	0,931	1,032	0,995
v r	18,700	18,700	18,700	18,700
v o	18,099	18,648	19,609	19,114
Pd ap	11775	13345	16593	14641
w	0,209	0,209	0,209	0,209
t	0,163	0,163	0,163	0,163

Fig.12. Results regarding propeller design Ship 2 draught+0.5.

	Ship 5				
	Case I	Case II	Case III	Case IV	Case V
Pb	16020	16020	16020	19920	19920
n0 [rpm]	117	117	117	105	105
nc	9	9	9	9	9
Cu	0,750	0,850	0,850	0,850	0,750
D	6,163	6,010	6,182	6,891	6,870
n(p) [rpm]	112,964	117,000	117,000	105,000	101,378
z	5	5	5	5	5
Ae/A0	1,050	1,050	1,050	1,050	1,050
P/d	0,902	0,993	0,939	1,033	0,999
v r	18,700	18,700	18,700	18,700	18,700
v o	18,199	18,699	18,713	19,609	19,141
Pd ap	11775	13345	13345	16593	14641
w	0,205	0,205	0,205	0,205	0,205
t	0,163	0,163	0,163	0,163	0,163

Fig.13. Results regarding propeller design Ship 5 draught+0.5.

The maximum values of the propellers diameters that can be fitted behind the stern of the studied ships hulls, are maximum 5.89m for ship 2 draught+0.5 and 6.01m for ship 5 draught+0.5. These values have been calculated and measured on the 2D shape lines plan taking into considerations the requirements related to the clearance between propeller and hull structure [3]. The propeller diameter is limited on the one hand by the distance between lower blade's tip and the baseline (from safety condition to avoid damages) and on the other hand by the clearance between propeller and the ship hull to avoid high level of pressure pulses, noises and vibrations. Usually, these distances are given in percent of diameter.

In the case of engine 1, for both studied ships, due to the higher power and lower revolution rate, large values of diameters for the optimal propellers have been obtained. In an attempt to comply with the clearance requirements, the second engine with a lower power and a higher revolution rate has been chosen for propulsive performances investigation.

For Ship 2 draft+0.5, the most favourable case from the required speed performances point of view was case II from Figure 12, but unfortunately it does not comply with the requirements regarding the clearance and safety of propeller from construction point of view.

For Ship5 draft+0.5, the most favourable case from the required speed performances point of view was case III from Figure 13, but unfortunately it does not comply with the requirements regarding the clearance and safety of propeller from constructive point of view. That's why, for this variant of ship shapes and for the second case of motorisation, a compromise has been made regarding the propeller's design.

The engine with 16020 kW brake power and 117 rpm has been chosen, and the maximum constructively acceptable diameter has been imposed D=6.01 m instead of efficiency optimal diameter D=6.182. As a results of the propeller diameter reduction, a decrease in ship's speed has been obtained, from 18.713 knots to 18.699 knots. It results a classic case of compromise in propeller design when a propeller with optimal diameter in terms of efficiency cannot be placed behind the stern of the ship from constructive reasons.

Another solution to solve the problem would be to search and find other combination main engine propeller, but it must be taken into account that, in general, slow diesel engines of high power have low revolution rate, which leads to large propeller diameter.

It can be seen that the stern shapes for the Ship 5 lead to a slight reduction of the wake coefficient, ensuring a better uniformity of the flow in propeller disc. A CFD analysis of flow phenomenon around these shapes would be useful for studying the influence of ship shapes on the propulsive performances.

4. CONCLUDING REMARKS

The paper presents the second stage of a study regarding the ship hull forms influence on the propulsive performances for an imposed capacity containership. In the first stage, starting from a given containership, other ten ship hulls have been generated and the ships resistance have been computed. In the second stage, for two of the new gewnerated ship hull forms with lowest resistance, the propulsion systems have been designed, encountering problems with the placement of the optimal propeller in the after end of the ship. This focused the present study on the changing the dimensions and shapes of the aft end for these two ships, in an attempt to fit the optimal propeller diameter in term of propulsive efficiency, as large is possible.

Thus, starting from two of the ship's hull forms with lower resistance another 6 new ship hulls have been generated, deriving by turn, the main dimensions beam, length and draught with 0.5 m. The hydrodynamic ships resistance for the new 6 ships hulls generated have been computed and analysed and two hulls (Ship 2 draft+0.5 and Ship 5 draft+0.5) with lowest hydrodynamic resistance have been selected to continue the study. The necessary propulsive power has been computed, two slow diesel engines have been selected and for every case, an optimal propeller in terms of efficiency has been designed.

There were still problems to fit the optimal propeller diameter in the stern area, which finally led to the choice of shapes of Ship 5 draft+0.5, in the second case of motorisation, with the maximum propeller diameter from constructive point of view. It resulted a classic case of compromise in propeller design when a propeller with optimal diameter in terms of efficiency cannot be placed behind the stern of the ship from constructive reasons, but in this case the ship's velocity with the selected propulsion system was very close to the owner's required speed.

In the future third stage, aspects regarding the influence of ships forms on the propulsive performances considering the IMO EEDI (Energy Efficiency Design Index) requirements will be analysed.

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