THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620, e-ISSN 2668-3156
2021

SHIP RESISTANCE PERFORMANCES ASSESSMENT FOR A CONTAINERSHIP

Victor-Marian Cocris
University "Dunarea de Jos" of Galati,
Faculty of Naval Architecture, Galati, Domneasca Street, No. 47, 800008, Romania,
E-mail: cocrisvictor@gmail.com

Mihaela Amoraritei
University "Dunarea de Jos" of Galati,
Faculty of Naval Architecture, Galati, Domneasca Street, No. 47, 800008, Romania,
E-mail: mihaela.amoraritei@ugal.ro

ABSTRACT

The present work is focused on ship resistance performances assessment for a given capacity containership. Starting from the main dimensions of a parent ship, other ten hull forms have been generated using DELFTship free program. For each case, the hydrodynamic ship resistance has been calculated using an inhouse code. The objective was to modify some geometrical parameters to obtain shapes of the hull that would provide the least resistance at the required transport capacity. The results obtained will be used in a future analysis related to the impact of hull forms improvements and ship resistance reduction on the propulsive performance and CO_2 emissions per transport work.

Keywords: ship resistance, ship hull forms, containership

1. INTRODUCTION

Hull forms optimization and ship resistance decreasing may play an important role in improving the propulsion performances of a new ship and meeting the IMO requirements related the Energy Efficiency Design Index (EEDI), to reduce the CO_2 emissions per transport work. In the preliminary design stage, the ship resistance performances evaluation is necessary for the selection of the optimal hull shapes and propulsive power calculation, for propulsion system design to absorb minimum power with maximum efficiency, with minimum fuel consumption and reduced associated gasses emissions.

The present paper is focused on ship resistance performances assessment for a given capacity containership. Starting from a parent ship already existing in Dragomir Ships Shapes Album [1] other ten hull forms have been generated using DELFTship free program. The ship resistance has been computed for each case, in order to obtain hull forms that would provide the least resistance at the required transport capacity.

First of all, the DELFTship program database was searched and all container ships were brought to roughly the same dimensions as the parent ship. Ten new hull forms (2D and 3D models) have been generated with DELFTship program and the hydrostatic calculations were performed for all cases. The new hulls shapes have differed mainly in the extremities of the bow and stern, thus a series of geometrical parameters required for ship resistance calculation had different values. Rhino7 program was used for an accurate measurement of different surface areas, information needed to prepare the input data for the following computations.

For each case, the hydrodynamic ship resistance has been calculated using an inhouse code based on Holtrop-Mennen method. The results have been plotted and compared to select the hull forms with the minimum resistance and which can meet the ship owner requirements regarding the transport capacity at the desired speed. The ship resistance inhouse program has been developed by the first author during undergraduate studies and the results have been validated using the PHP code developed at the Naval Architecture Faculty from Galati.

The obtained results will be used in a future analysis related to the impact of ship resistance reduction and hull forms improvements on the propulsive performances taking into consideration the EEDI requirements (CO_2 emissions per transport work).

2. SHIP RESISTANCE CALCULATION CODE

Ship resistance evaluation is important both for the choice of the optimal hull shapes and the necessary propulsive power calculation. Ship resistance is an important input data in propulsive system design, in order to find the best combination between ship hull, main engine and propeller, with minimum absorbed power and maximum efficiency, minimum fuel consumption and reduced associated gasses emissions, at the required cargo capacity with the desired speed.

In the preliminary design stage, theoretical methods based on statistical analysis of systematic data from the literature can be used for ship's resistance calculation. The Holtrop-Mennen method is one of the used statistical methods, based on a regression analysis of model tests and full-scale data, available at the Netherlands Ship Model Basin [2]. The method can be applied to different displacement type ships with limits of applicability function of Froude number, prismatic coefficient Cp and ratios between the main dimension of the ship Lwl- length on waterline, B-bradth, T-draught. The method may also be applied outside the following limits, but the accuracy decreases.

- oil tanker, bulk carriers ($Fn \le 0.24$; $0.73 \le Cp \le 0.85$; $5.1 \le LWL/B \le 7.1$; $2.4 \le B/T \le 3.2$);
- container ship, destroyers($Fn \le 0.45$; $0.55 \le Cp \le 0.67$; $6.0 \le LWL/B \le 9.5$; $3.0 \le B/T \le 4.0$);
- trawlers, coastal tugs, tugs($Fn \le 0.38$; $0.55 \le Cp \le 0.65$; $3.9 \le L_{WL}/B \le 6.3$; $2.1 \le B/T \le 3.0$).

According to the Holtrop-Mennen method, the total ship resistance can be computed using the formula:

$$R_t = R_{F\,(1+k)} + R_{APP} + R_W + R_B + R_{TR} + R_A \quad (1)$$

where:

R_F -the frictional resistance according with ITTC-1957 formula,

(1+k)-form factor describing the viscous resistance of the hull form in relation to R_F

R_{APP} - resistance of appendages

R_W - wave-making and wave-breaking resistance

R_B - additional pressure resistance of bulbous bow near the water surface

R_{TR} - additional pressure resistance of immersed transom stern

R_A - model-ship correlation resistance

For the hydrodynamic ship resistance calculation an inhouse code (NGU) based on Holtrop-Mennen method has been developed by the first author during undergraduate studies. Thus, a friendly interface (Figure 1) has been created, transposing the Holtrop-Mennen method in the c# language with the "Visual Studio 2019" program.

Fig. 1. The inhouse code interface

The results have been compared and validated with those of an existing code PHP at the Faculty of Naval Architecture and they have been plotted in Figure 2.

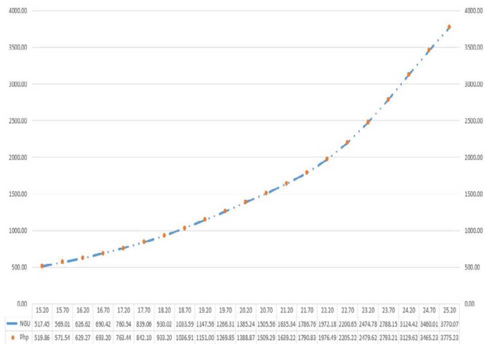


Fig. 2. Ship resistance code results validation

Taking into account that the results were very close, the inhouse code has been used in the present work.

3. MODEL SHIP CHARACTERISTICS

A given capacity containership (1805 TEU) already existing in Dragomir Ships Shapes Album [1] has been selected as parent ship. Their main characteristics are:

- Length over all…..….173,950 [m]
- Floating length……...166,000 [m]
- Beam……………..…27,300 [m]
- Draught……………..8,500 [m]
- Floating area………..4175,123 $[m^2]$
- Master section area…226,051 $[m^2]$
- Block coefficient……0,752
- Displacement………28965.000 [t]

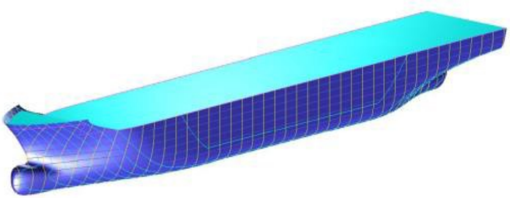


Fig. 3. 3D model geometry of the parent containership [1]

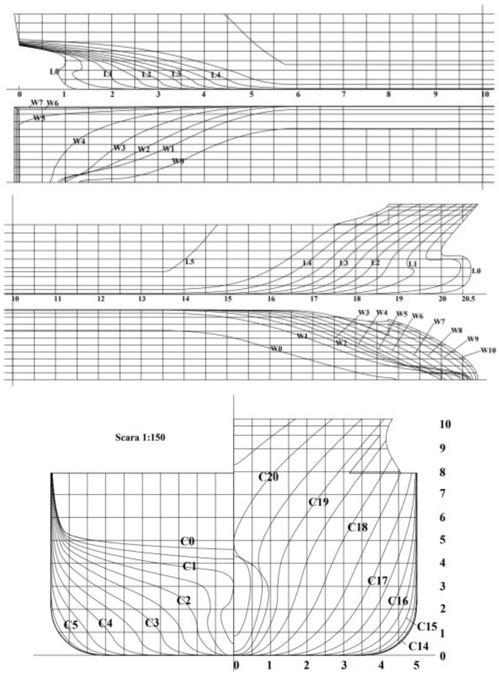


Fig. 4. Parent containership shape lines [1]

4. SHIP HULL FORMS GENERATION. RESULTS

Starting from the main dimensions of the parent ship, other ten hull forms have been generated using DELFTship free program. This 3D hull forms modeler program is "designed to be visual and intuitive", provides a database with models, easy 3D design features and hydrostatic details" [3].

First of all, the DELFTship program database was searched and all container ships were brought to roughly the same dimensions as the parent ship. Ten new hull forms (2D and 3D models) have been generated with DELFTship program and the hydrostatic calculations were performed for each case. The new hulls shapes have differed mainly in the extremities of the bow and stern, thus a series of geometrical parameters required for ship resistance calculation had different values. For parameters such as: water plane area A_{wl}, midship section area A_m, block coefficient c_b, prismatic coefficient c_p, transverse bulb area A_{bt}, the immersed part of the transverse area of the transom at zero speed, have been obtained different values. Rhino7 program was used for an accurate measurement of the surface areas needed to prepare the input data for the following computations. The main geometrical characteristics of the new ship hulls generated for this study are presented in Table 1 and the 2D/3D ships lines plans and 3D models are presented in Figures 5-34.

5. SHIP RESISTANCE CALCULATION. RESULTS

For each case, the ship resistance has been calculated using the inhouse code (NGU) based on Holtrop-Mennen method. The calculation has been performed for a given range of speeds. The results regarding the total ship resistance for a given range of speed are plotted in Figure 35, and the total resistance, resistance components and hull propeller interaction coefficients are given for 20.2 knots speed in Figure 36 and Tables 2,3. The results have been plotted and compared to select the hull forms with the minimum resistance but which can meet the ship owner requirements regarding the transport capacity at the desired speed.

The purpose of the present work was to choose those forms of the ship that offer a minimum resistance in order to design the propulsion system and did not aim at an analysis of the influence of different geometric parameters on the ship resistance. It is observed that the lowest resistance has been obtained for the ship 2. In the same time, for this hull shapes forms, the values of the hull propeller interaction coefficients are lower, ensuring a better hull efficiency value for cvasipropulsive coefficient calculation.

Table 1. The main geometrical characteristics of the new ship hulls

	1805 T.E.U	Ship 1	Ship 2	Ship 3	Ship 4	Ship 5	Ship 6	Ship 7	Ship 8	Ship 9	Ship 10
Ltotal	173.95	168.012	171.500	170.048	167.385	160.068	172.536	167.079	167.218	167.745	171.432
Lwl	166	166.009	166.015	166.027	166.012	166.014	166.002	166.004	166.002	166.001	166.005
B	27.3	27.300	27.301	27.300	27.300	27.300	27.300	27.300	27.300	27.300	27.300
T	8.5	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500
Ta	8.5	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500
Tf	8.5	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500
Awl	4175.12312	4081.170	4040.700	4207.700	4175.650	3934.480	4068.760	4063.350	4020.630	3968.140	4177.130
Am	226.051011	226.815	228.093	229.524	226.764	225.626	226.682	221.495	220.668	224.266	228.812
Abt	20.4474698	13.811	21.716	5.925	11.606	16.616	5.144	9.924	11.734	9.874	9.044
At	8.73506141	31.868	11.439	36.309	61.757	2.496	18.003	22.703	16.516	12.835	21.790
Disp vol	28965	28965.845	28864.226	28927.313	28914.359	28913.904	28887.471	28990.646	28927.342	28917.347	28928.712
n	1.1883E-06	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V(kts)	20.2	20.200	20.200	20.200	20.200	20.200	20.200	20.200	20.200	20.200	20.200
cb	0.75194118	0.752	0.749	0.751	0.751	0.751	0.750	0.753	0.751	0.751	0.751
cp	0.77189639	0.769	0.762	0.759	0.768	0.772	0.768	0.788	0.790	0.777	0.762
H(const)	13.5	13.500	13.504	13.500	13.500	13.500	13.500	13.500	13.500	13.502	13.500
Rt NGU	1385.24231	1463.741	1261.262	1577.545	1689.868	1323.440	1471.827	1552.463	1520.747	1404.986	1466.413
Rt Php	1388.87176	1464.201	1265.715	1577.664	1690.072	1324.636	1471.943	1552.634	1520.999	1405.107	1466.540
t	0.16213745	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.185	0.162	0.162
w	0.23604431	0.236	0.235	0.238	0.235	0.234	0.234	0.236	0.322	0.234	0.237
nR	1.0071572	1.007	1.007	1.006	1.007	1.007	1.007	1.008	1.009	1.008	1.006

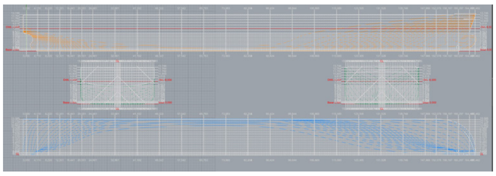


Fig. 5. Ship 1, 2D shape lines

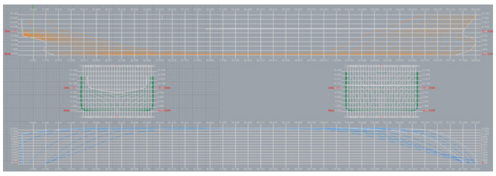


Fig. 6. Ship 2, 2D shape lines

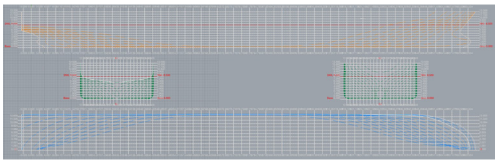


Fig. 7. Ship 3, 2D shape lines

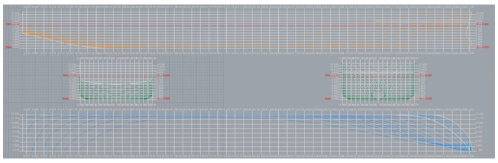


Fig. 8. Ship 4, 2D shape lines

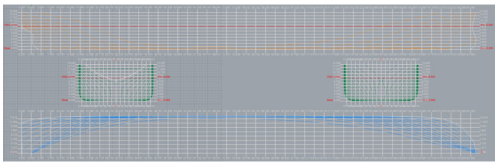


Fig. 9. Ship 5, 2D shape lines

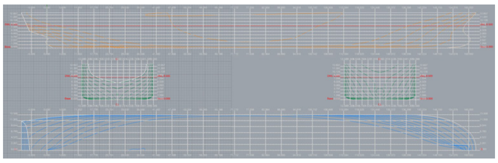


Fig. 10. Ship 6, 2D shape lines

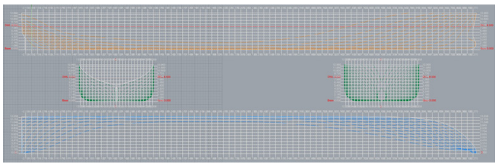


Fig. 11. Ship 7, 2D shape lines

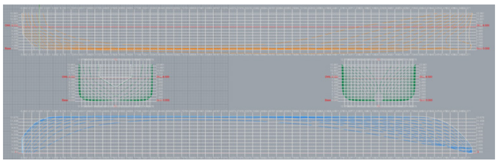


Fig. 12. Ship 8, 2D shape lines

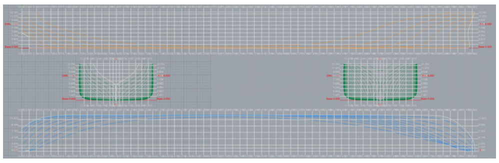


Fig. 13. Ship 9, 2D shape lines

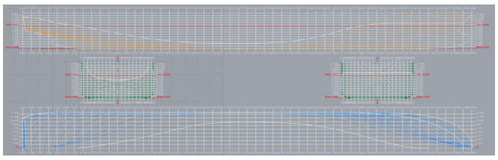


Fig. 14. Ship 10, 2D shape lines

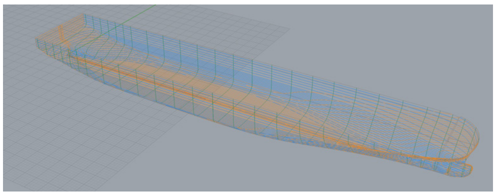


Fig. 15. Ship 1, 3D model-lines

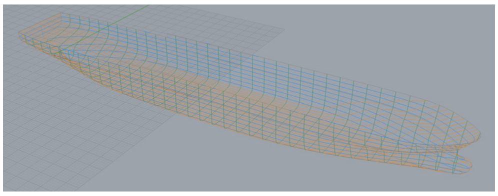


Fig. 16. Ship 2, 3D model-lines

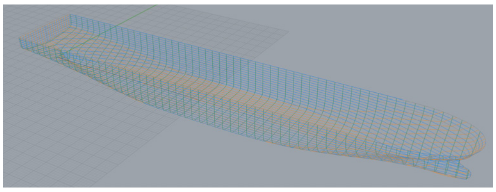


Fig. 17. Ship 3, 3D model-lines

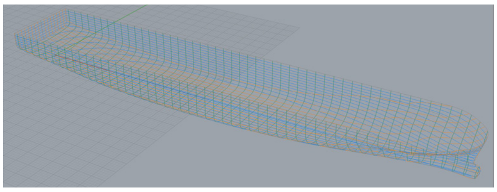


Fig. 18. Ship 4, 3D model-lines

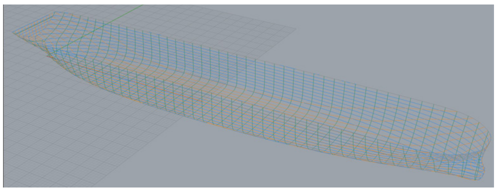


Fig. 19. Ship 5, 3D model-lines

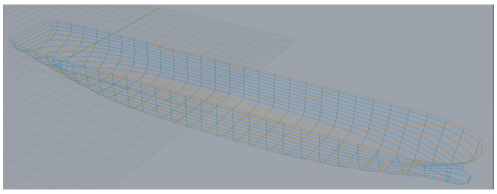


Fig. 20. Ship 6, 3D model-lines

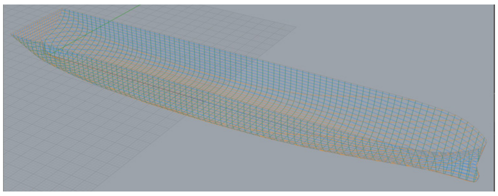


Fig. 21. Ship 7, 3D model-lines

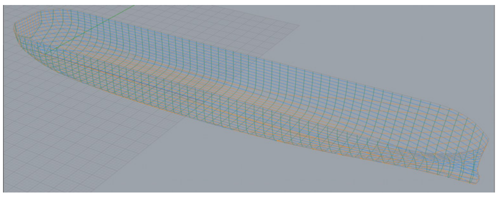


Fig. 22. Ship 8, 3D model-lines

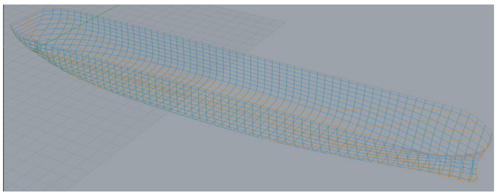


Fig. 23. Ship 9, 3D model-lines

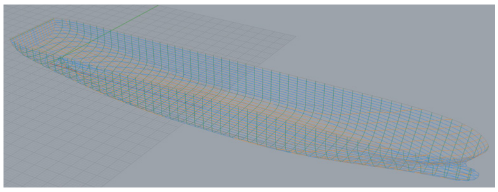


Fig. 24. Ship 10, 3D model-lines

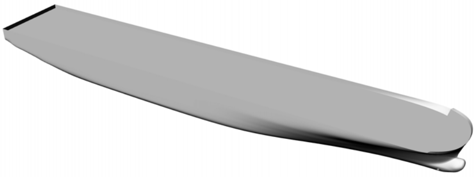


Fig. 25. Ship 1, 3D model-surface

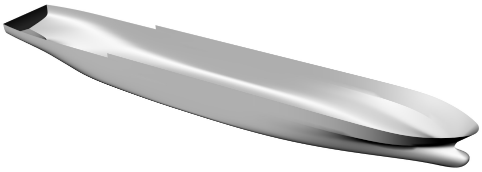


Fig. 26. Ship 2, 3D model-surface

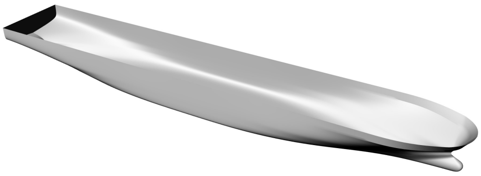


Fig. 27. Ship 3, 3D model-surface

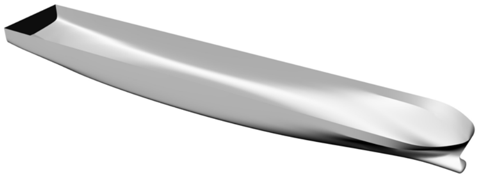


Fig. 28. Ship 4, 3D model-surface

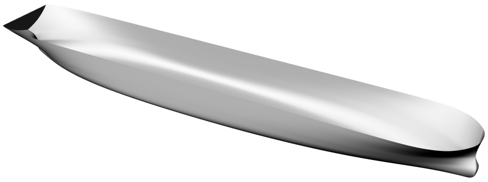


Fig. 29. Ship 5, 3D model-surface

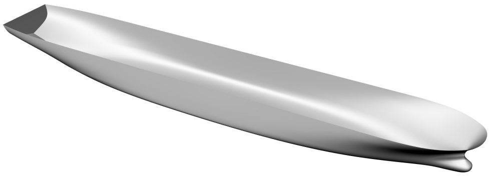


Fig. 30. Ship 6, 3D model-surface

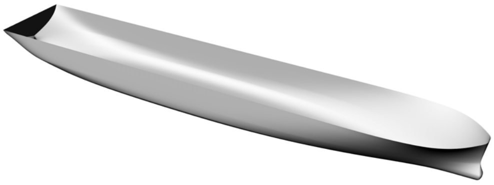


Fig. 31. Ship 7, 3D model-surface

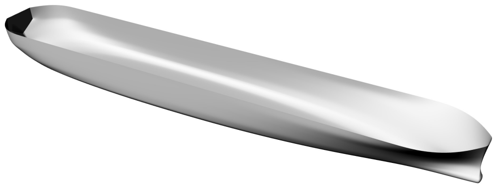


Fig. 32. Ship 8, 3D model-surface

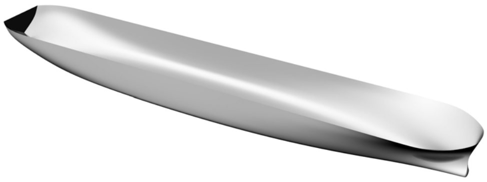


Fig. 33. Ship 9, 3D model-surface

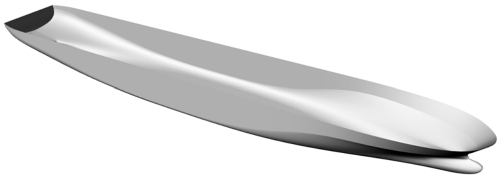


Fig. 34. Ship 10, 3D model-surface

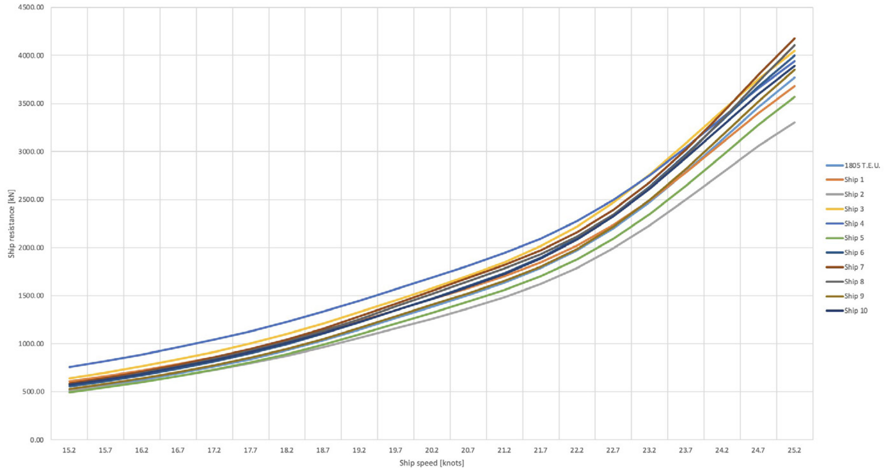
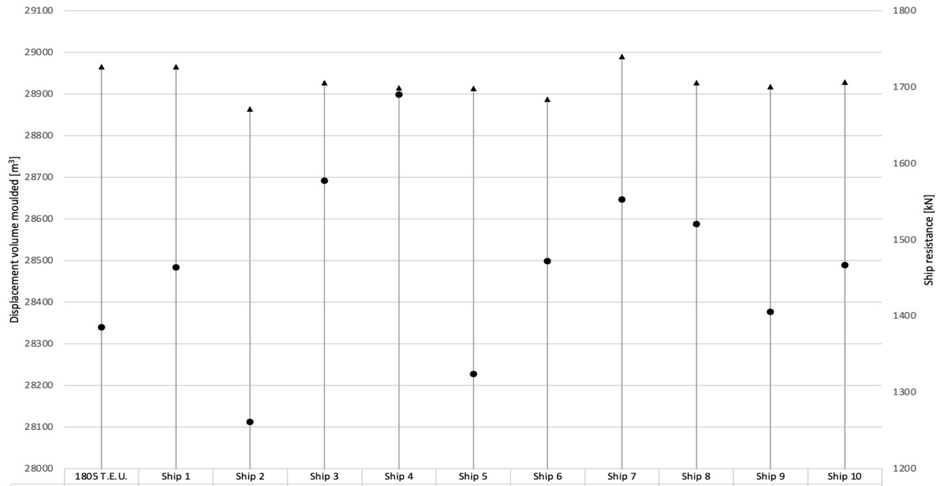


Fig. 35. Ship resistance versus ship speed for the analysed cases



	1805 T.E.U.	Ship 1	Ship 2	Ship 3	Ship 4	Ship 5	Ship 6	Ship 7	Ship 8	Ship 9	Ship 10
cb	0.751941184	0.752	0.749	0.751	0.751	0.751	0.750	0.753	0.751	0.751	0.751
cp	0.771896394	0.769	0.762	0.759	0.768	0.772	0.768	0.788	0.790	0.777	0.762
▲ Disp vol	28965	28965.845	28864.226	28927.313	28914.359	28913.904	28887.471	28990.646	28927.342	28917.347	28928.712
Awl	4175.12312	4081.170	4040.700	4207.700	4175.650	3934.480	4068.760	4063.350	4020.630	3968.140	4177.130
Am	226.051011	226.815	228.093	229.524	226.764	225.626	226.682	221.495	220.668	224.266	228.812
Abt	20.4474698	13.811	21.716	5.925	11.606	16.616	5.144	9.924	11.734	9.874	9.044
At	8.73506141	31.868	11.439	36.309	61.757	2.496	18.003	22.703	16.516	12.835	21.790
● Rt NGU	1385.242312	1463.741	1261.262	1577.545	1689.868	1323.440	1471.827	1552.463	1520.747	1404.986	1466.413

Fig. 36. Total ship resistance at the required speed for the new ship hulls.

Table 2. Ship resistance and hull propeller interaction coefficients results for the new ship hulls

	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 NGU	1385.24231	1463.741	1261.262	1577.545	1689.868	1323.440	1471.827	1552.463	1520.747	1404.986	1466.413
Rt Php	1388.87176	1464.201	1265.715	1577.664	1690.072	1324.636	1471.943	1552.634	1520.999	1405.107	1466.540
t	0.16213745	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.185	0.162	0.162
w	0.23604431	0.236	0.235	0.238	0.235	0.234	0.234	0.236	0.322	0.234	0.237
nR	1.0071572	1.007	1.007	1.006	1.007	1.007	1.007	1.008	1.009	1.008	1.006

Table 3. Results regarding total ship resistance and components for the new ship hulls at the required speed.

	v[kn]	v[m/s]	Rt[kn]	Ra[kn]	Rapp[kn]	Rw[kn]	Rb[kn]	Rf[kn]	Fr	Rn[m/s]
1805 T.E.U.	20.20	10.39	1385.24	138.24	2.66	663.47	0.00	496.37	0.26	1451545539.46
Ship 1	20.20	10.39	1463.74	136.59	2.66	609.97	0.00	490.45	0.26	1451624237.72
Ship 2	20.20	10.39	1261.26	136.55	2.66	551.14	0.00	490.29	0.26	1451676703.22
Ship 3	20.20	10.39	1577.54	137.90	2.66	687.17	0.00	495.20	0.26	1451781634.22
Ship 4	20.20	10.39	1689.87	137.59	2.66	584.82	0.00	494.06	0.26	1451650470.47
Ship 5	20.20	10.39	1323.44	134.63	2.66	620.35	0.00	483.39	0.26	1451667958.97
Ship 6	20.20	10.39	1471.83	135.65	2.66	724.24	0.00	487.06	0.26	1451563027.96
Ship 7	20.20	10.39	1552.46	135.59	2.66	764.80	0.00	486.84	0.26	1451580516.46
Ship 8	20.20	10.39	1520.75	134.96	2.66	749.56	0.00	484.55	0.26	1451563027.96
Ship 9	20.20	10.39	1404.99	134.48	2.66	691.98	0.00	482.82	0.26	1451554283.71
Ship 10	20.20	10.39	1466.41	137.66	2.66	685.71	0.00	494.29	0.26	1451589260.71

6. CONCLUSIONS

In the presents study, the ship resistance performances evaluation for a given capacity containership has been performed. Starting from a parent ship already existing, other ten hull forms have been generated using DELFTship free program and the ship resistance have been computed for each vessel using an in house code. The aim was to obtain hull forms that would provide the least resistance at the required transport capacity and desired speed, to design the propulsion system by finding the best combination between ship hull, main engine and propeller, with maximum efficiency and minimum fuel consumption.

The purpose of the present work was to choose those forms of the ship that offer a minimum resistance in order to design the propulsion system and did not aim at an analysis of the influence of different geometric parameters on the ship resistance.

The results obtained will be also used in a future analysis related to the impact of hull forms improvements and ship resistance reduction on the propulsive performances to meet the IMO requirements related the Energy Efficiency Design Index (EEDI), to reduce the CO_2 emissions per transport work.

Acknowledgements

The present research has been performed in the frame of the Naval Architecture Research Centre from the Naval Architecture Faculty of Galati.

REFERENCES

[1]. **Dragomir, D.,** *" Ships Shapes Album'',* Dunarea de JosUniversity Foundation Publishing House, 2014

[2]. **Holtrop, J., Mennen, G.,G.,J.,** *"An Approximate power prediction method''* Int Shipbuilder Prog 1982; 29: 166–170.

[3]. https://www.delftship.net/

Paper received on November 10th, 2021

