

A comparative review of the resistance of a 37,000 dwt Chemical Tanker based on experimental tests and calculations

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Abstract. The evaluation of ship resistance is of paramount importance having a decisive impact on the economic performances and efficiency depending on mission. If new IMO requirements through the Energy Efficiency Design Index (EEDI) are taken into account the necessity to have more and more accurate tools capable to consider the influences of different parameters became mandatory. The availability of towing tank facilities and the full scale trials are the practical means in order to be able to confirm the accuracy of theoretical formulations and to define the limits of CFD applications. Based on the results of the towing tank tests, a direct comparison with the results provided by classical methods and CFD computations can be systematically can be performed. On the other hand, the influences of the modifications operated on the fore part of the ship are theoretically evaluated and compared with the towing tank results. Consequently, the paper is focused on the comparison of the results evaluated using different tools which have been carried out for a Chemical Tanker built by Constanta Shipyard Romania.

1. Introduction

The evaluation of ship resistance is playing a role of more and more increasing importance as far as the new challenges related to the strict regulations adopted by IMO related to the emission of air pollutants from ships. The energy-efficiency measures to reduce emissions of greenhouse gases under Annex VI of

IMO's pollution prevention treaty (MARPOL) became mandatory. IMO has established a series of baselines regarding the amount of fuel to be burned by each type of ship for a certain cargo capacity [3], [4].

Consequently, the designer is in the position to carry out an important amount of researches and to find appropriate solutions in order to be able to reach the new targets.

The application was performed for a 37,000 Dwt Chemical Tanker which was built before the new regulations were issued by IMO. The analysis is more important since a large series of 21 ships of this type have been built by Constanta Shipyard Romania and the data base obtained during trials can be further used to confirm both the towing tank results predictions and the theoretical ones, respectively.

The main characteristics of the ship are presented below.



Figure 1. General view of a ship from the series (Courtesy of Constanta Shipyard)

Table 1. Main characteristics of the ship	
Main characteristics	Value
Length overall, L_{OA} [m]	179.96
Length of waterline, L_{WL} [m]	175.00
Length between perpendiculars, L_{BP} [m]	172.00
Breadth moulded, B [m]	32.00
Depth, D [m]	16.50
Draught, T [m]	10.50
Volumetric displacement, ∇ [m ³]	46318.5
Deadweight, Δ_{WT} [t]	37000.00
Bare hull wetted surface, S [m ²]	7906.8
Design speed, v [Kts]	15.00
Block coefficient, C_B	0.7828
Midship section coefficient, C_M	0.9937
Prismatic coefficient, C_P	0.7878

2. The evaluation of ship resistance using classical formulations

As a first step of the analysis the calculations have been carried out using classical formulations for the evaluation of ship resistance.

During the initial design stage, the most popular method is the formulation given by Holtrop-Mennen, which, in fact, is based on a large number of experimental results and the formulas used for the calculations have been obtained using multi parameter regression technique [5]. The other two methods used in the application, also based on the experimental results, were Taylor-Gertler one and Guldhammer-Harvald respectively, but the evaluations are made based on systematic diagrams.

The results are numerically presented in Table 2 and graphically in Figure 2. It can be observed that for the service speed, $v = 15$ Knots, there are significant differences between the results provided by above mentioned methods. The availability of the results provided by investigations using towing tank tests

Being by far the most popular and complex one Holtrop – Mennen method was investigated in order to find which parameter could be reconsidered in order to match the experimental results. It was found that closer values are obtained if the distance of bulb immersion, h_b , is modified. A value of $h_b = 4.64$ m produced a significant modification of the resistance as it can be seen in Table 4 and Figure 4, respectively.

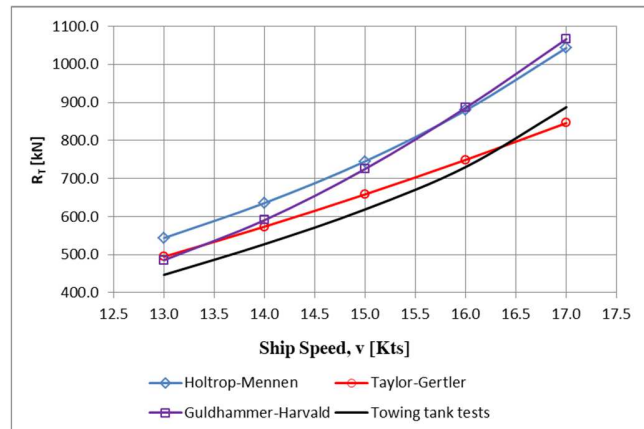


Figure 3. Comparative diagram; towing tank results – preliminary methods

Table 4. Comparative results with modified Holtrop-Mennen method			
v [Kts]	Holtrop-Mennen (initial)	Holtrop-Mennen (modified) R_T [kN]	Towing tank results
13	543.67	448.25	446.9
14	635.68	530.01	527.63
15	745.19	630.19	618.99
16	879.19	756.08	730.38
17	1043.14	913.47	887.38

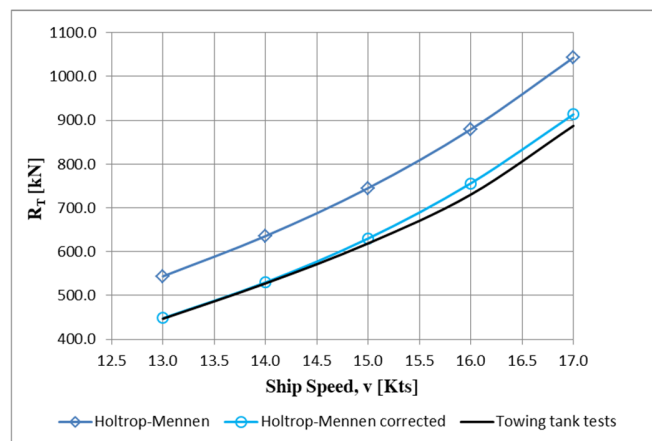


Figure 4. Influence of modifications on the results using Holtrop-Mennen method

According to the results reported [6] some slight modifications on the bow, where a small vertical position was made, may lead to a positive effect on the hydrodynamic resistance of the ship. As suggested by the owner, a new solution was tested in the towing tank. The modification can be observed in Figure 5.

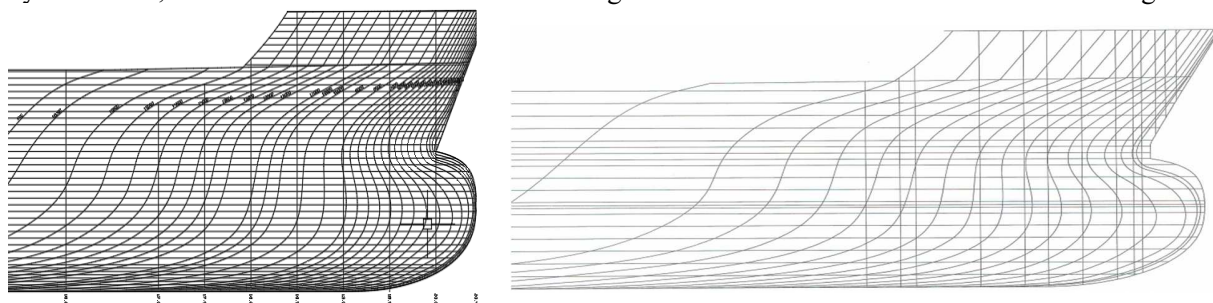


Figure 5. The proposed modification of the bow area (left-initial; right-proposed)

The results of the towing tank tests are comparatively presented in Table 5 and Figure 6.

Table 5. Influence of bow modification

v [Kn]	Initial shape	Modified shape
	R_T [kN]	
13	543.67	446.9
14	635.68	527.63
15	745.19	618.99
16	879.19	730.38
17	1043.14	887.38

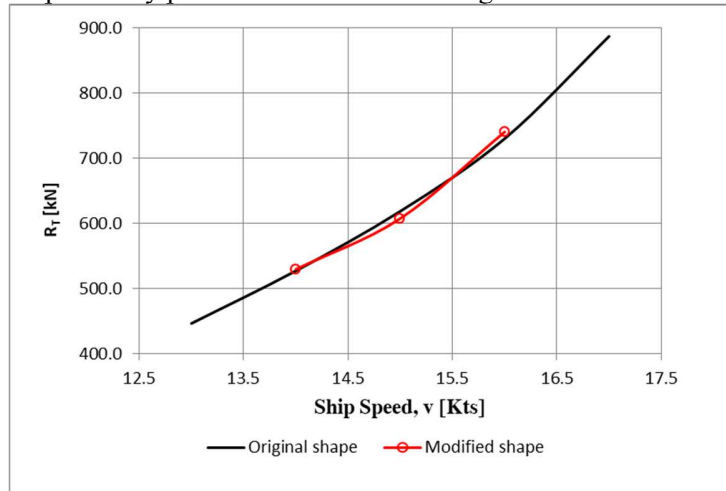


Figure 6. Towing tank results for the two tested shapes

A small reduction of about 2% was obtained and the important thing is that there are still possible to improve if strong tools, like experimental facilities, are available. Another powerful tool to be investigated is the CFD one.

4. Computational Fluid Dynamics (CFD) results

Based on the availability of experimental results, and to be able to have a direct comparison, an application has been developed using a 3D computer code. The calculations have been performed for the original shape as well as for the modified one to evaluate the sensitivity of the simulations compared with the experimental results. The results are presented in Table 6 and Figure 7.

Table 6. Influence of bow modification using towing tank tests and CFD results

Ship speed v [Kn]	Towing tank tests		CFD	
	Initial shape	Modified shape	Initial shape	Modified shape
R_T [kN]				
14	527.63	529.99	498.20	467.00
15	618.99	607.84	603.55	582.06
16	730.38	740.68	725.90	722.39

It can be observed that between the two approaches there are significant differences, mainly related to the modified case. Practically, the complexity of the geometry of the modified form could create complications and, consequently, a special care has to be devoted. It is also important to observe that the smaller speeds lead to higher differences and for higher speeds the results are converging to the similar values. Due to such aspects, the towing tank tests remain the most reliable tools when complex forms are considered.

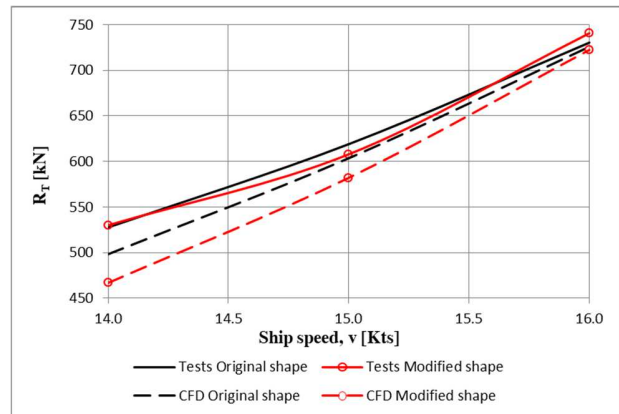


Figure 7. Towing tank tests and CFD results

On the other hand, CFD calculations represent an important approach, providing important information related to the pressure distribution, the own waves system, etc. An example related to the own wave profiles are presented in Figure 8.

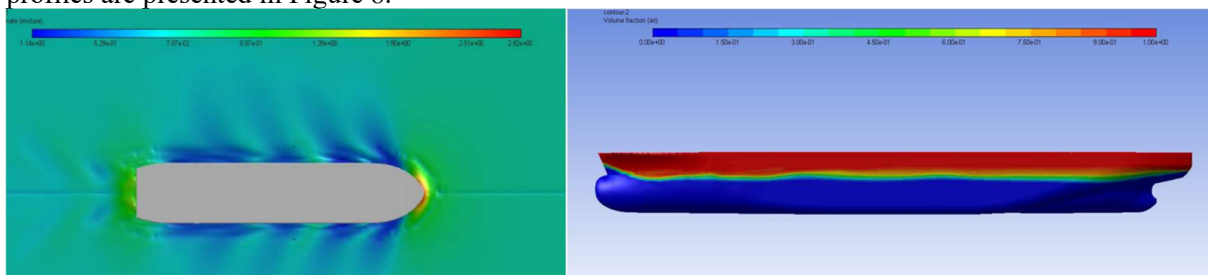


Figure 8. Own wave profile: left – top view; right – lateral view

5. Evaluation of Energy Efficiency Design Index (EEDI)

The evaluation has been carried out based on existing procedure. In fact, the above mentioned index represents the impact on the environment due to shipping versus the benefit to the society coming from shipping ^{[1], [2], [7]}. The most important thing is that the new rules have to be observed and is mandatory to comply with, each five years the limits becoming more and more restrictive:

- Phase 0 → 1 January 2013 – 31 December 2014
- Phase 1 → 1 January 2015 – 31 December 2019 (a reduction of 10%)
- Phase 2 → 1 January 2020 – 31 December 2024 (a reduction of 20%)
- Phase 3 → 1 January 2025 and later (a reduction of 30%).

The evaluations have been performed using the coefficients for recommended for oil tankers which are presented in Table 7.

Table 7. The EEDI [gCO₂/tNM] values depending on ship deadweight

DWT [t]	Phase 0	Phase 1	Phase 2	Phase 3
1000	41.873	37.686	33.498	29.311
2000	29.856	26.87	23.885	20.899
3000	24.496	22.047	19.597	17.147
4000	21.288	19.159	17.03	14.901
5000	19.091	17.182	15.273	13.364
7500	15.664	14.098	12.531	10.965
10000	13.612	12.251	10.89	9.529
12500	12.208	10.987	9.766	8.546
15000	11.169	10.052	8.935	7.818
20000	9.706	8.735	7.765	6.794
25000	8.704	7.834	6.964	6.093
30000	7.963	7.167	6.371	5.574
35000	7.386	6.648	5.909	5.17
40000	6.92	6.228	5.536	4.844
45000	6.534	5.88	5.227	4.574
50000	6.206	5.586	4.965	4.344
55000	5.924	5.332	4.739	4.147
60000	5.678	5.11	4.542	3.975
65000	5.46	4.914	4.368	3.822
70000	5.267	4.74	4.213	3.687

The calculated value for the EEDI is 4.943 which is represented in Figure 9 to be compared with the limits given in Table 7.

The important observation is that the value of the index is below all limiting curves, i.e. it is fully complying with the requirements.

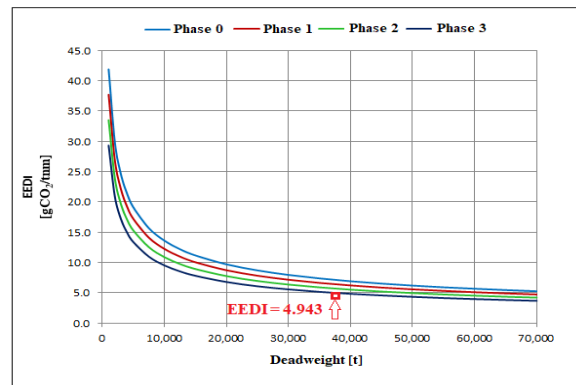


Figure 9. The value of the EEDI for the investigated ship

Conclusions

The present paper, based on an extensive survey related to ship resistance topics, intends to underline that the increasing importance related to the accuracy of the results to be used in early design stages requires more and more powerful tools.

It was noticed that even trustful methods, widely used could lead to significant errors, the main reason being the tendency to use more and more sophisticated solutions due to new requirements related to pollutions but also due to increase ship efficiency.

The results show that the utilization of modern tools like CFD ones have to be carefully used mainly when sophisticated forms are considered.

Another important observation is the continuous necessity to have valuable experimental facilities able to carry out and develop new forms and to confirm the theoretical evaluations.

The paper also proves that a combination of reliable tools, both theoretic and experimental may lead to performant solutions.

The next step to be performed is to compare the present results with full scale trials results for this large series of ships. As it is well known, full scale results are the only ones to be used for the validation of the results obtained during the design process.

Acknowledgements

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References

- [1] C.B.R.X.M.D.R. Naya Olmer, Greenhouse Gas Emissions from Global Shipping, 2013–2015, The International Concil on Clean Transportation, 2017
- [2] Diaconița A.I., Crudu L., 2018 „On the Influences of Main Engine Parameters on EEDI Evaluation for a Bulk Carier”, Annals of the University „Dunarea de Jos” of Galati, Fascicle XI – Shipbuilding, Year XXXV, pp. 107-112, Galati University Press, Galați, ISSN 1221-4620;
- [3] IMO, „Low carbon shipping and air pollution control,”
- [4] IMO, Ship Energy Efficiency Regulations and Related Guidelines, London: IMO, 2016
- [5] Obreja, D., “Teoria navei, Concepte și metode de analiză a performanțelor de navigație” (In Romanian), București: Editura Didactică și Pedagogică, 2005
- [6] Pirvulescu R., Alexandru G., Simion A. “Model tests for Chemical Tanker 37000 Dwt, AC 4648-03, Icepronav SA, March 2006
- [7] Resolution MEPC.212(63), Annex 8, 2012 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) .