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THE REDUCTION OF THE MAIN ENGINE'S POWER FOR A 15000 TDW CHEMICAL TANKER REGARDING THE ACHIEVEMENT OF EEXI AND ITS INFLUENCE ON MANOEUVERABILITY

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ABSTRACT

EEXI was established as a measure for assessing the energy efficiency of existing vessels and aims to reduce CO_2 in order to achieve IMO regulations. The purpose of this study is to calculate the EEXI for a 15000 twd chemical tanker and further evaluate the impact of this change on ship manoeuvrability. EEXI estimations were conducted using different approaches while manoeuvrability performances were evaluated by means of different simulation programs. The purpose of this study revolves around striking a balance between optimal operation and achieving energy efficiency.

Keywords: manoeuvrability, EEXI, turning circle, sea trials

1. INTRODUCTION

One of the most important factors of main engine power reduction is meeting the energy efficiency requirements for the ship, thus reducing the greenhouse gas emissions of the vessel in question.

Shipping is responsible for about 90% of international trade because it is an efficient, cheap, and fast means of transportation. It is therefore an important contributor to climate change due to the significant volume of emissions produced every year. As a consequence of this fact, regulations regarding energy efficiency and compliance are mandatory and represent an essential step for a world that is becoming more and more concerned about protecting the environment. At the same time, this change can lead to significant technological development in the maritime sector to compensate for this loss of power. New solutions such as electric or hybrid propulsion systems, renewable energy sources, or energy recovery systems can be explored.

Furthermore, engine power reduction can contribute to substantial fuel economies, which in time lead to the reduction of operational costs for the vessel. This improves the rentability of the ship.

Apart from assessing the positive aspects of this change, it is important to analyse its impact on the manoeuvrability performances of the ship.

Despite the benefits, this operation implies a change in the handling of the ship. Engine power reduction, thus ship speed reduction leads to a greater response time. That means the ship will not execute manoeuvres as promptly. Not only that, but the reduction in main engine power required the propeller to be redesigned.

2. SHIP DESCRIPTION

The analysis was conducted on a 15000 tdw chemical tanker, named STX Infinity, which was one of a series of 6 sister ships built by STX Braila Shipyard (now VARD Romanian Shipyards) in Romania. According to the definition established by MARPOL, a chemical tanker is a ship destined to transport chemical substances with different degrees of risk [1].

Table 1 presents the main characteristics of the ship.

Table 1 Main characteristics of the ship

L_{PP} [m]	149.6
L_{WL} [m]	139.25
B [m]	22.2
D [m]	12.25
T [m]	8.5
v [Kn]	14
C_B	0.585
Main Engine MCR [kW]	5760
Main Engine Rpm	550
Propeller type	CPP
Propeller diameter [m]	5.8

This ship is equipped with a shaft generator, which provides the advantage of a short supply of energy in case the vessel deals with any extreme situations at sea.

Fig. 1. STX Infinity

3. SHIP RESISTANCE ESTIMATION

The total resistance of the ship is the force working against its movement. It is made up of a series of components, such as: frictional resistance, residual resistance, and air resistance, which can vary depending on the type, characteristics of the ship, and sea conditions [2].

Resistance is heavily influenced by these factors: ship speed, shape of the hull, environmental conditions (wind, currents, waves), depth of the sea, etc [2].

3.1 Method

In this case, the chosen method was Holtrop-Mennen, and the estimations were conducted using Excel and other programs that make use of this method. The programs needed for this estimation were PHP (Preliminary Hydrodynamics Performances), PPP (Power Prediction Program), and another specialized software. Information regarding the shape of the hull, characteristics of the engine, rudder and propeller, and speed have been introduced in each of these programs [10].

3.2 Results

Estimations for a series of three speeds have been made and all results have been compared with those obtained in the towing tank trials.

Figure 2 highlights all the values obtained for each method of estimation used. In addition to the chart, Table 2 presents the errors between the estimation conducted with the selected methods and the results of the towing tank trials for the service speed (14 knots).

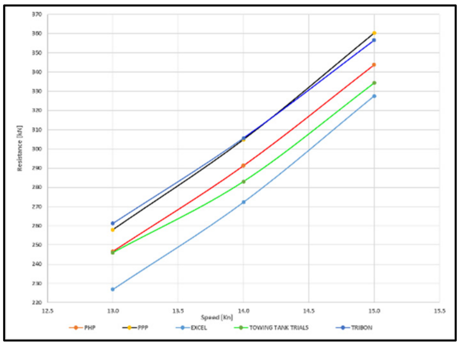

Fig. 2. Comparative chart for resistance

Table 2. Errors

Method	**RT [kN]**	**Errors [%]**
Towing Tank	283.03	-
EXCEL	272.255	3.81%
PHP	291.280	-2.91%
PPP	304.912	-7.73%
SPECIALIZED SOFTWARE	305.600	-7.97%

All methods used were within a margin of error of about 8%. The differences are due to the variable amount of information required by each of these programs to run the analysis.

The most satisfactory results were obtained in the case of classical Excel calculation and for the PHP program, with errors of a maximum of 4%.

4. EEXI

4.1. General Information

As of 2018, IMO has adopted a strategy for reducing greenhouse gases emissions resulting from maritime transport. By default, a series of mandatory measures have been established. Such measures are EEDI (Energy Efficient Design Index) and EEXI (Energy Efficient Existing Ships Index) [3], [4].

EEDI is strictly applied in the case of new ships and it estimates the amount of CO_2 in grams that a ship produces per one transport operation. On the other side, EEXI is only applicable to existing ships and is one of the newer requirements, introduced in 2023 [3], [4].

The regulations of EEXI apply to all ships involved in international voyages that have a capacity of more than 400 GT. There are also exceptions for which this set of rules does not apply, such as: ice breakers, drilling, and ships that have unconventional propulsion systems [3], [4].

4.2. Methods of estimating EEXI

To comply with the EEXI regulations, ships are obliged to calculate an 'attained EEXI', which represents the value of the index at that specific time and a 'required EEXI', which is the value of the EEXI accepted by the norms. The acquired value should be lower than the limit established in the regulations [5], [6], [10].

In this paper, EEXI has been estimated using three approaches:

- Initial information (case 1);
- Data from towing tank trials (case 2);
- Data from sea trials (case 3);

The formulas and criteria needed to be met for this estimation were presented in multiple IMO resolutions.

$$attained\ EEXI = \frac{(P_{ME} \times C_{FME} \times SFC_{ME}) + (P_{AE} \times C_{FAE} \times SFC_{AE})}{Deadweight \times V_{REF}} \left[\frac{g}{tMm}\right]$$

Fig. 3. Attained EEXI

$$required\ EEXI = \left(1 - \frac{X}{100}\right) \times EEDI\ Reference\ Line \left[\frac{g}{tMm}\right]$$

Fig. 4. Required EEXI

The attained EEXI formula contains important parameters, such as:

- Information about the main and auxiliary engines: power and specific fuel consumption for 75% MCR;
- Ship's reference speed corresponding to 75% MCR;

- Deadweight;
- A series of factors highly dependent on the ship type;

The required EEXI formula is strictly based on ship type and deadweight [5]. Thus, it will have the same value for each of the cases considered in this paper.

In the case of calculations based on towing tanks or sea trials, the reference speed has been estimated using specific data obtained during the trials.

Valuable information such as the speed-power diagram and data collected from sea trials have been therefore used.

In both cases, the speed of the ship has been estimated according to the main engine's power, using interpolation.

4.3. Results

All of the results are presented in Figure 5 and Table 3.

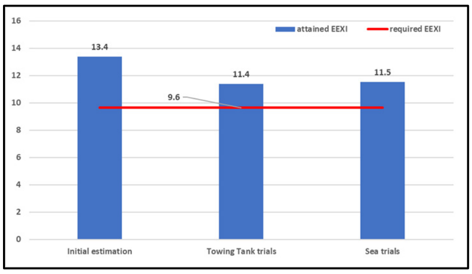

Fig. 5. EEXI graph

Table 3. EEXI results

	Case 1	Case 2	Case 3	M.U.
Attained EEXI	13.39	11.38	11.53	gCO_2
Required EEXI	9.63	9.63	9.63	gCO_2

In addition to the first graph, an additional one has been created so as to better compare the results of the methods. The value estimated using information from sea trials was the reference for the comparison.

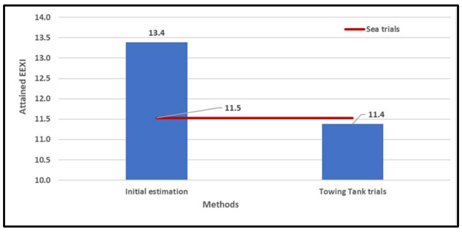

Fig. 6. Results comparison

The differences in these values stem mainly from the ship's reference speed variation throughout the cases of analysis. In the first stage, it was estimated without considering the fact that, during trials, the vessel had achieved a much higher speed compared to service speed. In the case of towing tank and sea trials, EEXI was calculated based on interpolation, which further led to more accurate values for the ship's reference speed and more similar results.

The most accurate result is obtained with the data from sea trials, which was used in the following part of the study.

4.4 Power reduction

To comply with energy efficiency regulations, the owner of the ship can choose two options. The first one implies the reduction of speed by implementing either an EPL (Engine Power Limitation) or a ShaPoLi system (Shaft Power Limitation). The other option involves the reduction of energy required for ship propulsion, which can be implemented by using hybrid propulsion systems, energy recovery technologies, or the usage of alternative fuel [7], [10]. The usage of an EPL system has been considered for this paper.

An additional EEXI estimation has been conducted using the values determined for case 3, sea trials. The new calculations were based on the speed-power diagram of the ship. The power of the main engine has been gradually reduced, and the corresponding speed has been extracted from the diagram. In this manner, an accurate estimation was made.

$$attained\ EEXI = \frac{(P_{MElim} \times C_{FME} \times SFC_{ME}) + (P_{AE} \times C_{FAE} \times SFC_{AE})}{Deadweight \times V_{REFlim}} \left[\frac{g}{tMm}\right]$$

Fig. 7. EEXI Formula

The new formula is presented in Figure 7. In this case, the power introduced in the formula is 83% of the power limitation. At the same time, the values for the specific fuel consumptions have been changed.

Table 4. EEXI after power reduction

Parameters	Value	M.U.
Attained EEXI	9.56	gCO_2
Required EEXI	9.63	gCO_2

For a new power of 3735 kW, which corresponds to a ship speed of 13.4 knots, the EEXI achieved by the vessel would be 9.56 gCO_2, thus leading to energy efficiency compliance.

This is achieved by a power reduction of 35% and a speed decrease of 0.6 knots.

5. Manoeuvrability

The purpose of this chapter is to highlight how power reduction affects performance and manoeuvrability. Simultaneously, the requirements established by ITTC (International Towing Tank Conference) and IMO regarding manoeuvrability must be respected. ITTC is an organization dealing with the estimation of hydrodynamic performance of ships, based on a series of physical and numerical experiments. Along with IMO, it provides information related to the main ship manoeuvres, important aspects of performance, standards, and recommendations. The standards apply when trials are conducted for both starboard and portside, deep-sea conditions, and full load.

5.1 Turning circle

In this paper, a thorough analysis of the turning circle manoeuvre has been performed. The trials have been conducted for both port and starboard at approach speed with a maximum rudder angle (35 degrees). According to IMO, the approach speed is to be at least 90 % of the ship's speed corresponding to 85% MCR [8], [9], [10].

Essential aspects obtained during trials are [9]:

- tactical diameter (TD);
- advance (Av);
- transfer (Tr);
- steady turning diameter (STD);
- loss of speed on steady turn;

The requirements for this manoeuvre are as follows [9]:

- The advance parameter is not to exceed 4.5 ship lengths;
- The tactical diameter is not to exceed 5 ship lengths;

5.2 Analysis

The analysis has been conducted using the following programs:

- PHP;
- MPP;
- Specialized software;

Cases of analysis:

- engine power before limitation (case I);
- engine power after limitation (case II);
- increased propeller diameter after engine power limitation (case III);

The third case implies a redesigned propeller with a diameter of 6.3 meters.

Simulations for an increased diameter of the propeller have been conducted with the purpose of finding another solution to the subject of the paper.

Information about hull shape, main characteristics, details regarding the bulb, appendices of the ship, propeller, bow thruster, and speed have been introduced in each of these programmes.

5.3 Results

All the results obtained and IMO regulations for advance and tactical diameter have been presented in Figures 8 and 9, respectively Tables 5 and 6.

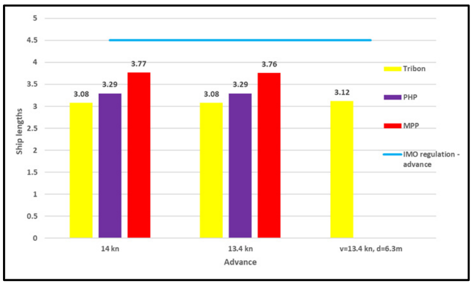

Fig. 8. Advance (Ad)

Table 5. Results for advance

Ad	I	II	III	IMO limits
PHP	3.29	3.29	-	4.5
MPP	3.77	3.76	-	
Specialized software	3.08	3.08	3.12	

Concerning the advance of the ship, there aren't any major differences obtained among the three cases of analysis. Not only are the results similar, which implies that the speed reduction of 0.6 knots doesn't significantly affect ship manoeuvrability, but they are also below the limit established by IMO.

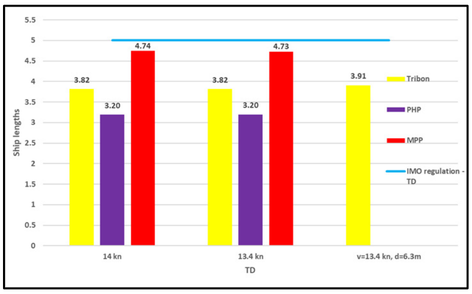

Fig. 9. Tactical Diameter (TD)

Table 6. Results Tactical Diameter

TD	I	II	III	IMO limits
PHP	3.20	3.20	-	5
MPP	4.74	4.73	-	
Specialized software	3.82	3.82	3.91	

A series of remarks can be made with respect to the chart and table earlier presented.

Firstly, it is visible that none of the results obtained for the different cases of analysis go over the limit established by IMO with concern to the tactical diameter parameter. Secondly, the differences between the first two cases of analysis are insignificant. Therefore, a speed reduction of 0.6 knots doesn't have a great impact on manoeuvrability.

To have a better view of the results, a comparison to data obtained in sea trials has been made.

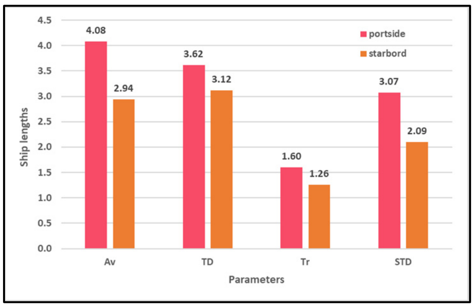

Fig. 10. Sea trials – Turning circle

Table 7. Sea trials results

Sea trials	Av	TD	Tr	STD
Portside	4.08	3.62	1.6	3.07
Starbord	2.94	3.12	1.26	2.09

Data presented in Figure 10 and Table 7 is significantly different from the results obtained in the conducted analysis. This stems from the inability to estimate sea conditions using programmes. In that manner, the conditions through which the trials have been conducted at sea cannot be introduced before running the analysis.

Using these two sets of data, a couple of affirmations can be made.

Firstly, compared to the other programmes, PHP provided results that were quite similar to the actual situation of the vessel. The differences between the analysed parameters were the lowest.

Secondly, each programme conducts the analysis in a specific manner, which leads to distinct parameters.

Lastly, factors such as waves, currents, wind, or ship speed heavily influence trial results.

6. Concluding remarks

In this paper, two important aspects concerning ship operation have been analysed: the percentage of power needed to be reduced in order for the vessel to achieve energy efficiency and the impact of this change on manoeuvrability.

Initially, an estimation of ship resistance wa been conducted by means of different programmes. Results were then compared to towing tank trial data. Although the methods required different amounts of information, all results have been close to one another, with a maximum error of 8%. The most satisfactory results were provided by PHP and Excel, the values being within a 3% error limit.

Regarding EEXI, the estimations have been conducted using three approaches: initial information (case 1), data from towing tank trials (case 2), and data from sea trials (case 3).

The most accurate results have been provided by case 3. Differences among results stem from the manner of estimating ship reference speed.

As for ship manoeuvrability estimation, the analysis has been made using different programmes and the results have been compared with sea trials data. Similar to EEXI estimation, the performance was evaluated for different situations: engine power before limitation (case I), engine power after limitation (case II), and increased propeller diameter after engine power limitation (case III).

Following the simulations, it has been proven that environmental factors and ship speed have a significant influence on the outcome of the analysis.

The obtained results were within the IMO regulations concerning manoeuvrability.

As a conclusion to this study, it can be stated that a reduction in engine power of 35% meets the EEXI requirements for the analysed vessel and does not significantly impact manoeuvrability performance.

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REFERENCES

[1] "Chemical tanker," *Wikipedia*. Nov. 30, 2023. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Chemical_tanker&oldid=1187591591

[2] "Curs_RIN_2022-23.pdf."

[3] "Initial IMO GHG Strategy." [Online]. Available: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx

[4] "IMO sustainable shipping amendments for EEDI, EEX, CII and BWM." [Online]. Available: https://marine-offshore.bureauveritas.com/updated-imo-amendments-bring-sustainability-forefront

[5] "Outlines of EEXI regulation.pdf." Accessed: Apr. 19, 2024. [Online].

Available: https://www.classnk.or.jp/hp/pdf/activities/statutory/eexi/eexi_rev3e.pdf

[6] "EEXI: Achieving Vessel Compliance | Hellenic Shipping News Worldwide." [Online]. Available: https://www.hellenicshippingnews.com/eexi-achieving-vessel-compliance/

[7] "Top 4 ways to comply with EEXI without slowing down your vessels," Wartsila.com. [Online]. Available: https://www.wartsila.com/insights/article/complying-with-eexi-how-to-speed-up-decarbonisation-without-slowing-down-vessels

[8] D. Obreja, L. Crudu, and Sădiţa. Păcuraru, *Manevrabilitatea navei*. Galaţi: Galati University Press, 2008.

[9] "MSC.137(76).pdf."

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