A PRELIMINARY PROPULSIVE PERFORMANCES EVALUATION FOR AN OIL TANKER TO MEET EEDI CHALLENGE

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ABSTRACT

To control CO₂ emissions from ships, the International Maritime Organization (IMO) has introduced a mandatory technical measure for new ships: the Energy Efficiency Design Index (EEDI). The paper presents a preliminary evaluation of the propulsive performances for a 30000 tdw oil tanker, considering EEDI regulations. Ship resistance and propulsive power have been computed and several main diesel engines have been selected. For every study case, an optimal efficiency propeller has been designed and the Energy Efficiency Design Index has been calculated.

Keywords: Energy Efficiency Design Index (EEDI), ship propulsion performances

1. INTRODUCTION

Maritime transport is an important source of air pollution. In 2015, the ships involved in international trade contributed with about 2.6% of global CO₂ emissions [1]. To control CO₂ emissions from shipping, the International Maritime Organization (IMO) has introduced mandatory technical measure for new ships: the Energy Efficiency Design Index (EEDI).

As a measure of the ship energy efficiency, EEDI can be expressed as CO₂ emissions versus transport work. The CO₂ emissions are influenced by the installed power of the main and auxiliary engines as well as the quality and quantity of fuel burned in them. The transport work is expressed function of two important parameters in EEDI formula: speed and ship capacity. Energy Efficiency Design Index is focused mainly on less polluting equipments and has a significant impact on ship propulsion system design and in the whole ship design process.

The paper presents a preliminary study of propulsive performances for a 30000 tdw oil tanker, considering EEDI regulations. According data to International Council of Clean Transportation Report [1], oil tankers are responsible for 13% from the total shipping CO₂ emissions (Figure1).

Fig.1. Shipping CO₂ emissions
In the present work, ship resistance and propulsive power have been computed and several main diesel engines have been selected. For every study case an optimal efficiency propeller has been designed and the Energy Efficiency Design Index has been calculated.

2. SHIP PROPULSIVE PERFORMANCE EVALUATION

The present study has been focused on the design of the propulsion system for a 30000 tdw oil tanker, with the following main dimensions:

- Length on the waterline: 173.65 [m]
- Breadth: 26 [m]
- Design draught: 10.5 [m]

Ship resistance, effective power and necessary propulsive power have been computed. Effective power defined as ship resistance multiplied with ship speed has been plotted in Figure 2.

![Fig.2. Effective power](image)

Six engines slow Diesel engines have been selected for tanker propulsive performances investigations. For every study case an optimal four bladed propeller has been designed to absorb minimum power and to give maximum efficiency. The propellers have been designed taking into consideration 15% SM (Sea Margin) and 10% EM (engine margin). The results regarding propeller characteristics and ship performances are presented in Tables 1-6.

Table 1. Ship/propeller propulsive performances - case1,2

| Cases 1, 2 | Engine | Propeller | Ship |
|-----------|--------|-----------|------|
|           | Power [kW] | 6950      |      |
|           | Speed [rpm] | 111       |      |
|           | Number of cylinders | 5        |      |
| Diameter [m] | 6        |           |      |
| Pitch ratio P/D | 0.69     |           |      |
| Blade area ratio | 0.5     |           |      |
| Efficiency | 0.5612 |           |      |
| Ship speed [knots] | 13.95   |           |      |

Table 2. Ship/propeller propulsive performances – case3

| Case 3 | Engine | Propeller | Ship |
|--------|--------|-----------|------|
|        | Power [kW] | 6950      |      |
|        | Speed [rpm] | 130       |      |
|        | Number of cylinders | 5        |      |
| Diameter [m] | 5.47     |           |      |
| Pitch ratio P/D | 0.675    |           |      |
| Blade area ratio | 0.55     |           |      |
| Efficiency | 0.555   |           |      |
| Ship speed [knots] | 13.75   |           |      |

Table 3. Ship/propeller propulsive performances – case4

| Case 4 | Engine | Propeller | Ship |
|--------|--------|-----------|------|
|        | Power [kW] | 8340      |      |
|        | Speed [rpm] | 130       |      |
|        | Number of cylinders | 6        |      |
| Diameter [m] | 5.63     |           |      |
| Pitch ratio P/D | 0.694    |           |      |
| Blade area ratio | 0.58     |           |      |
| Efficiency | 0.5421  |           |      |
| Ship speed [knots] | 14.59   |           |      |
3. CALCULATION OF THE ENERGY EFFICIENCY DESIGN INDEX

In a simplified formula, the Energy Efficiency Design Index (EEDI) can be expressed as $\text{CO}_2$ emissions versus transport work.

$$EEDI = \frac{\text{CO}_2 \text{Emission}}{\text{Transport Work}}$$ (1)

The $\text{CO}_2$ emissions are given by main and auxiliary engines power multiplied with $\text{CO}_2$ conversion factor and specific fuel consumption. The transport work is expressed as ship speed multiplied with ship capacity. The formula is more complex, $\text{CO}_2$ emissions reduction due to innovative technologies may be added at numerator and different coefficients are used for particular situations (i.e. weather factor, capacity correction factors, etc).

The power of the main engines $P_{\text{ME}} [\text{kW}]$ is 75% of the rated installed power (MCR) and the auxiliary power $P_{\text{AE}}$ are taken as a fixed proportion of the main engine power (i.e. 5%MCR for MCR<10000kW) [2],[3]. The $\text{CO}_2$ conversion factor is a non-dimensional factor between fuel consumption and $\text{CO}_2$ emissions depending on the fuel type (i.e. for Diesel/Gas oil $C_F = 3.206$). The specific fuel consumption $\text{SFC} [\text{g/kWh}]$ is defined as quantity of fuel use per unit of engine power and may be found in the engine Technical File. $\text{SFC}$ for main engine is generally taken at 75% load and for auxiliary engines is generally taken at 50% load. Capacity depends on the ship type, i.e. for oil tanker, the deadweight should be used for capacity. Ship speed [knots] is an important parameter in ship propulsive performances analysis with a significant impact on EEDI regulations.

The attained EEDI computed using IMO guidelines has to be below the required EEDI specific on the ship type and size. A reference line (base line) is defined as:
where parameters $a$ and $c$ are given function of the ship type: for oil tanker: $a = 1218.8$ and $c = 0.488$.

The required EEDI has to be reduced relative to reference line (Phase 0) by percents each five years, depending on the ship types. For oil tankers with size in DWT between 4000 and 20000 and above, the % reductions in Required EEDI relative to Reference line are presented in Table 7.

**Table 7.** Reduction factor in % for the Required EEDI for oil tanker

| Oil tanker size [DWT] | Phase 0 (2013-2014) | Phase 1 (2015-2019) | Phase 2 (2020-2024) | Phase 3 (2025-) |
|-----------------------|---------------------|---------------------|---------------------|-----------------|
| 4000-20000            | -                   | 0-10                | 0-20                | 0-30            |
| 20000 and above       | -                   | 10                  | 20                  | 30              |

Six main engines have been chosen, but the case numbering has been made function of EEDI calculation. An engine with the same power/speed [rpm] characteristics has been selected for cases 1 and 2, but in the second case, EEDI has been computed using for fuel consumption the values obtained when the engine and turbocharger are matched to the lowest possible SFOC values while fulfilling the IMO Tier III emission limits [4].

The results regarding the attained EEDI have been plotted in Figures 3-9, to verify the computed values in comparison with reference line and the required EEDI corresponding to Phase 2 (2020-2024). In Table 8, the results regarding the attained EEDI have been centralized and the EEDI reduction from the EEDI base line has been analyzed versus ship speed.
The data related engine power versus attained EEDI has been plotted in diagram from Figure 10. The results regarding ship speed (obtained with the optimal efficiency designed propeller) versus attained EEDI have been plotted in Figure 11.

The best ship speed performances has been obtained with the higher power engine (case 4), but this was the worst case from the EEDI point of view. In the study cases, there was no EEDI reduction of 20% below the base line (corresponding to Phase 2, 2020-2024). With the lower power engine (case 6), the EEDI have been reduced by 19.83% below EEDI reference line, but the ship speed is far from the propulsive performances ex-
pecation. With the most efficient combination main engine/propeller (cases 1 and 2), EEDI have been reduced with 11.3%, 13.86% respectively. In these study cases, the ship speed (obtained with the optimal efficiency designed propeller) was close to the required speed. Higher propeller efficiency has been obtained for higher propeller diameter and lower rpm. In case 2, the EEDI reduction was more pronounced due to fuel oil consumption values while fulfilling the IMO Tier III emission limits, under the same power/ speed/ship capacity conditions.

In this preliminary stage of the propulsive performances evaluation for a 30000 tdw oil tanker, considering EEDI regulations, the EEDI requirements have not been meet. This proves once again that EEDI has become a real challenge for a naval architect, representing an important tool in ship propulsion system design. For the study ship, in the next stage, solutions to reduce the index will be sought by looking for new optimum engine/propeller combinations, by improving ship hydrodynamics forms and less structural mass.

4. CONCLUDING REMARKS

The paper presents an evaluation of the propulsive performances for a 30000 tdw oil tanker, considering EEDI regulations. Several combinations main engines/optimal efficiency propeller have been analysed, but, in this preliminary stage, the propulsion performances could not be achieved simultaneously with EEDI demands. This entails continuous efforts to improve ship design process, to fulfil all the requirements related to performances of a new ship: large cargo capacity, minimum fuel consumption with low emissions, maximal speed performances.

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REFERENCES

[1]. Omer, N., Comer, B., et all, “Green house Gas Emissions from Global Shipping, 2013-2015”, International Council of Clean transport Report, www.theicct.org/publications.

[2]. International Maritime Organization, “2014,2018 Guidelines on the method of calculation of the Energy Efficiency Design Index (EEDI)for new ships”, 2014, 2018

[3]. International Maritime Organization, “Procedure for calculation and verification of the Energy Efficiency Design Index (EEDI)”, 2013

[4]. Marine Engines Programme, Man Engines Solutions, 2ndEdition. 2019, https://marine.man-es.com/marine-engine-programme

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