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EFFECT OF MAIN VESSEL'S PARTICULARS ON ITS ATTAINED ENERGY EFFICIENCY DESIGN INDEX

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ABSTRACT

This paper presents a review on the Energy Efficiency Design Index (EEDI) implementation on ship performance and environment protection. The (EEDI) analyses is applied to three different types of ships; RoPax, yachts and tugs. Factors related to ship design parameters such as length, breadth, block coefficients, speed and engine model as related to EEDI are discussed. It was found out that length and speed are the most significant factors affecting the EEDI.

KEYWORDS: *Marine Energy, Marine Environment, Green House Gases GHG, IMO Regulation EEDI, Hydrodynamics Design*

INTRODUCTION

In order to control CO2 gas emission from shipping, the ship Energy Efficiency Design Index (EEDI) has been suggested by the IMO Marine Environment Protection Committee (MEPC) as a measure of the CO2 emission. The basic formulation of EEDI is predicated as the ratio of total CO2 emission per ton. mile. The amount of CO2 emission depends upon fuel consumption which depends upon the entire power requirements, this in turn will impact ship design parameters which are closely related to the economic performance of the ship.

IMO GHG STUDIES

Starting the 21th century, the first IMO study on Green House Gases emissions from ships was published, The study estimated that ships engaged in international trade contributed about 1.8 per cent of the planet total anthropogenic CO_2 emissions. [1]

The second IMO GHG study, published in 2009, estimated that international shipping emissions in 2007 to be 880 million tons, or about 2.7% of the worldwide total anthropogenic CO_2 emissions. [2]

The third IMO GHG study, published in 2014, estimated that international shipping emissions in 2012 is 796 million tons, or about 2.2% of the worldwide total anthropogenic CO_2 emissions. [3]

MEPC 74 initiated a fourth IMO GHG study, to be related by MEPC 76 in autumn 2020. This extra study is predicted to supply an update of GHG emissions estimates from international shipping from 2012 to 2018 and future scenarios for shipping emissions from 2018 to 2050. [4]

ATTAINED EEDI [5]

The attained EEDI shall be calculated for:

- each new ship;
- each new ship which has undergone a major conversion.
- each new or existing ship which has undergone so extensive major conversion, that is regarded by the Administration as a newly constructed ship.

EEDI Calculation: [6]

The Energy Efficiency Design Index can be expressed as:

$$EEDI = \frac{\text{Impact to the environment}}{\text{Benefit for the society}} = \frac{\text{Ship CO2 emissions}}{\text{Transprt Work}} \quad (1)$$

And the following equation is used to calculate its value in gm per ton mile

$$EEDI = \frac{f_j(P_{ME}\ X\ SFC_{ME}\ X\ C_{FME}) + (P_{AE}\ X\ SFC_{AE}\ X\ C_{FAE}) + \left((f_j . P_{PTI} - P_{AEeff})\ X\ SFC_{AE}\ X\ C_{FAE}\right) - (P_{eff}\ X\ SFC_{ME}\ X\ C_{FME})}{f_i\ X\ f_c\ X\ Capacity\ X\ V_{ref}\ X\ f_w}$$

Table 1: Explore the Different Parameters given in Equation: [6] (2)

Term	Unit	Brief description
Capacity	[Tonne]	Ship capacity in deadweight or gross tonnage at summer load linedraught (for container ships, 70% of deadweight applies).
C_{FAE}	[gCO_2/gfuel]	Carbon factor for fuel for auxiliary engines.
C_{FME}	[gCO_2/gfuel]	Carbon factor for fuel for main engines.
f_{eff}	[-]	Correction factor for availability of innovative technologies.
f_i	[-]	Correction factor for capacity of ships with technical/regulatoryelements that influence ship capacity.
f_c	[-]	Correction factor for capacity of ships with alternative cargo types that impact the deadweight-capacity relationship (e.g., LNG ships in gas carrier segment).
f_j	[-]	Correction factor for ship specific design features (e.g., ice-class ships).
f_w	[-]	Correction factor for speed reduction due to representative seaconditions.
n_{eff}	[-]	Number of innovative technologies.
n_{ME}	[-]	Number of main engines.
n_{PTI}	[-]	Number of power take-in systems (e.g., shaft motors).
P_{ME}	[kW]	Ship propulsion power that is 75% of main engine Maximum Continuous Rating (MCR) or shaft motor (where applicable); also taking into account the shaft generator. This will be influenced by alternative propulsion configurations.
P_{AE}	[kW]	Ship auxiliary power requirements at normal sea going conditions.
P_{AEeff}	[kW]	Auxiliary power reduction due to use of innovative electric power generation technologies.
P_{eff}	[kW]	75% of installed power for each innovative technology thatcontributes to ship propulsion.
P_{PTI}	[kW]	75% of installed power for each power take-in system (e.g., propulsion shaft motors).

Table 1 (Contd.,)		
SFC_{AE}	[g/kWh]	Specific fuel consumption for auxiliary engines as per NOx certification values.
SFC_{ME}	[g/kWh]	Specific fuel consumption for main engines as per NOx certification values.
V_{ref}	[knots]	Reference ship speed attained at propulsion power equal to P_{ME} andunder clam sea and deep-water operation at summer load line draught.

Required EEDI [7]

The attained EEDI value calculated by equation (2) should be less than a priori set value depending on ship type and her carrying capacity. This is given by a references line or base line for a group of vessels of the same type. The following relation is fitted to the collected data.

$$EEDI = a * b^{-c} \quad (3)$$

Where: a and c are constants and b is the vessel's carrying capacity. Table II shows the values for a, b and c for different types of ships.

Table 2: Parameters for Determination of EEDI Reference Value

Ship Type		a	b	c
2.25	Bulk carrier	961.79	DWT of the ship	0.477
2.26	Gas carrier	1120.00	DWT of the ship	0.456
2.27	Tanker	1218.80	DWT of the ship	0.488
2.28	Container ship	174.22	DWT of the ship	0.201
2.29	General cargo ship	107.48	DWT of the ship	0.216
2.30	Refrigerated cargo carrier	227.01	DWT of the ship	0.244
2.31	Combination carrier	1219.00	DWT of the ship	0.488
2.33	Ro-ro cargo ship (vehicle carrier)	$(DWT/GT)^{-0.7}$*780 where DWT/GT<0.3 1812.63 where DWT/GT≥0.3	DWT of the ship	0.471
2.34	Ro-ro cargo ship	1405.15	DWT of the ship	0.498
2.35	Ro-ro passenger ship	752.16	DWT of the ship	0.381
2.38	LNG carrier	2253.7	DWT of the ship	0.474
2.39 having	Cruise passenger ship non-conventional propulsion	170.84	GT of the ship	0.214

THE APPLICABILITY OF EEDI AND MODIFICATION FOR RORO, ROPAX, YACHTS AND TUGS

Table III and IV shows the CO_2 contribution of ships covered by EEDI IMO definition and those ships not covered by such definition.

Table 3: Current EEDI Coverage [8]

Covered by the Current EEDI Approach			
Ship Types	**Total CO2 Emissions**	**% of Total**	**Cumulative**
Crude oil tanker	112,769,764	10.1%	10.1%
Products tanker	43,378,360	3.9%	14.0%
Chemical tanker	64,139,731	5.7%	19.7%
LPG tanker	14,334,344	1.3%	21.0%
LNG tanker	33,250,235	3.0%	24.0%
Other tanker	2,377,084	0.2%	24.2%

Table 3 (Contd.,)			
Bulk	178,176,226	15.9%	40.1%
General cargo	95,915,792	8.6%	48.7%
Other dry-Reefer	19,220,666	1.7%	50.4%
Other dry-Special	1,050,811	0.1%	50.5%
Container	263,976,591	23.6%	74.1%
Vehicle	27,416,137	2.5%	76.6%
RoRo	18,250,134	1.6%	78.2%
Ferry-Pax	17,648,095	1.6%	79.8%
Ferry-RoPax	64,188,634	5.7%	85.5%
Cruise	21,307,727	1.9%	87.4%
Total EEDI coverage	**977,400,330**	**87.4%**	

Table 4: Ship Types not Covered by the Current EEDI Approach [8]

Not covered by the Current EEDI Approach			
Ship Types	**Total CO2 Emissions**	**% to Total**	**Cumulative**
Yacht	2,961,512	0.3%	87.7%
Offshore-Anchor handling T/S	343,305	0.0%	87.7%
Offshore-Crew/supply vessel	2,016,424	0.2%	87.9%
Offshore-Pipe(various)	1,694,125	0.2%	88.0%
Offshore-Platform supply	7,847,436	0.7%	88.7%
Offshore-Support/safety	1,287,720	0.1%	88.9%
Offshore-Tug supply	4,867,580	0.4%	89.3%
Service-Dredging	5,454,387	0.5%	89.8%
Service-Other	9,084,457	0.8%	90.6%
Service-Research	4,559,833	0.4%	91.0%
Service-SAR & patrol	2,399,215	0.2%	91.2%
Service-Tug	36,548,686	3.3%	94.5%
Service-Workboats	839,629	0.1%	94.6%
Miscellaneous-Fishing	22,606,670	2.0%	96.6%
Miscellaneous-Other	718,334	0.1%	96.6%
Miscellaneous-Trawlers	37,513,822	3.4%	100.0%
Total Non-EEDI Coverage	**140,743,136**	**12.6%**	

It is worth mentioning that in resort and touristic area (e.g., South Sinai area) aa large number of pleasure boats are operating and emitting large amount of CO_2. These vessels are not covered by EEDI. Also work boat like tugs and supply boats contribute a lot to CO_2 pollution.

These type of vessel are included in these present study.

CASE STUDY

Three different type of ships were selected to examine the effect of main dimension as well as type of engine and speed on their EEDI. These includes one type RoPax covered by IMO approach and the other two type yacht and tugs are not covered. RoPax ship (AL KAHARA), PRINCESS BASMA YACHT and EZZAT ADEL Suez Canal Tug. Results are shown on figure I through IV. Resistance and powering calculation were calculated based on Holtrop method. [9]

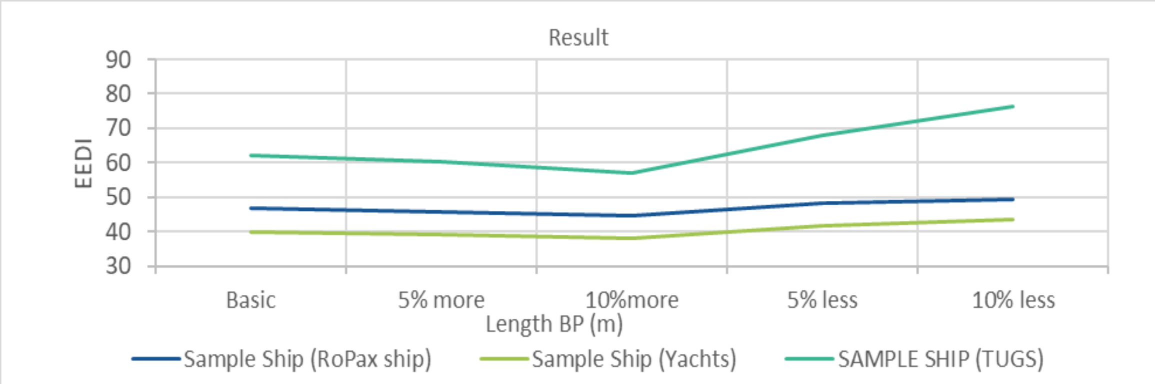

Figure 1: Change in Length of the Vessels.

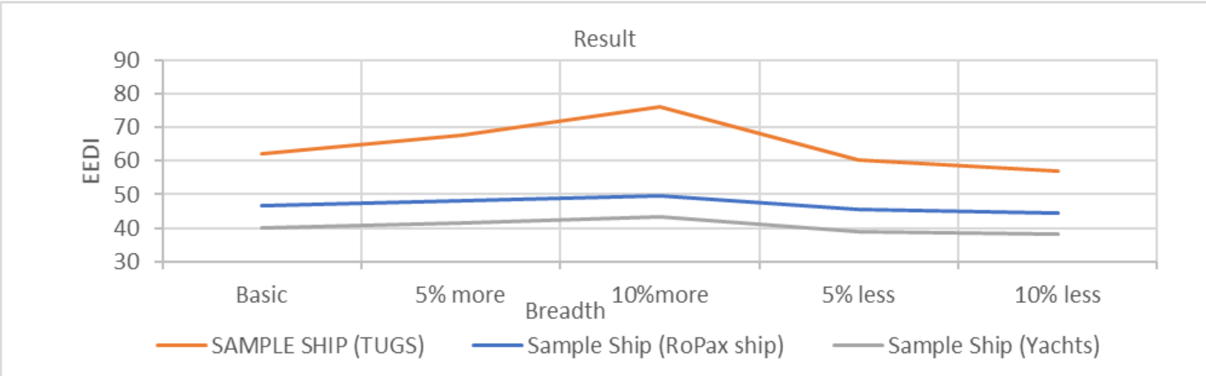

Figure 2: Change in Breadth of the Vessels.

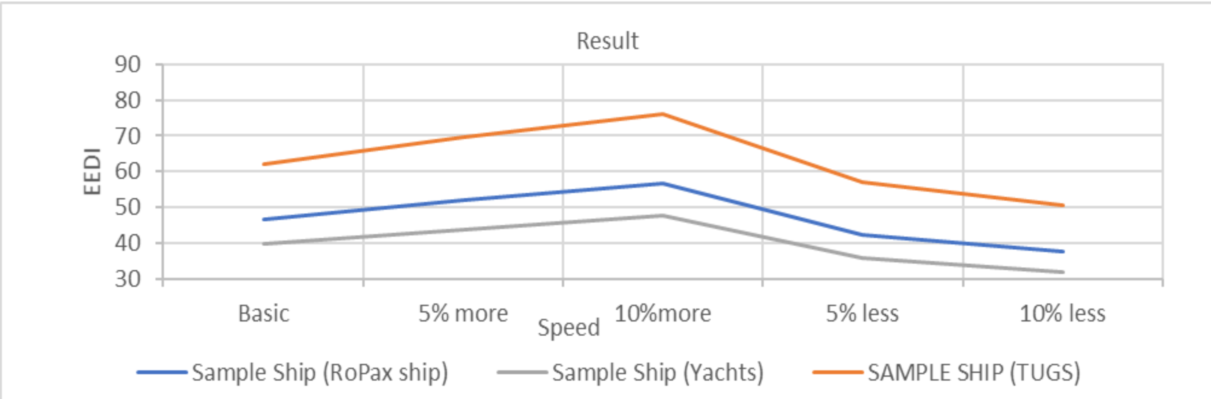

Figure 3: Change in Speed of the Vessels.

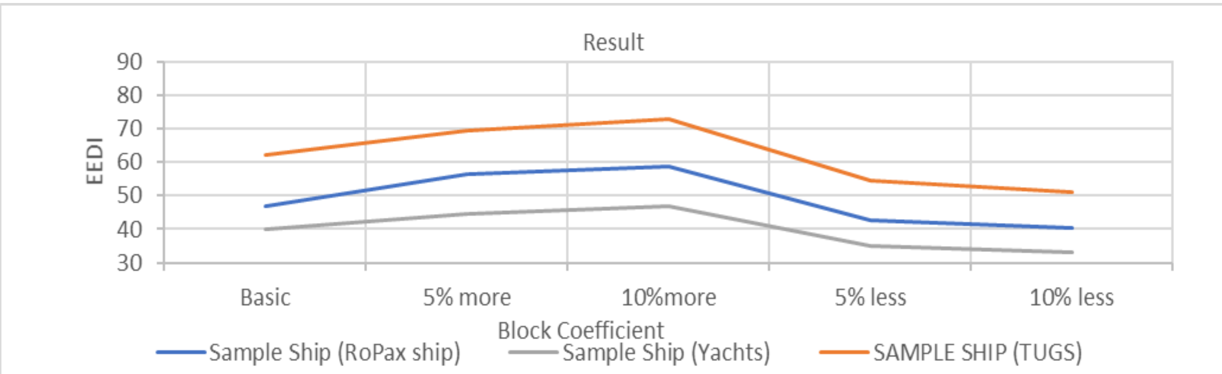

Figure 4: Change in Speed of the Vessels.

DISCUSSIONS

Figure I shows that increasing vessel's length has a favorable effect on the attained EEDI. The opposite is true for wider vessels; see Fig. II. It was also found out that reducing ship speed has a more significant EEDI for all types of ships examined. Finally, the study revealed that ships with lower block coefficient is more energy efficient; Fig. IV.

CONCLUSIONS

- Present study revealed that there are significate impacts for vessel dimensions on EEDI for the three different types.
- Eventhought it is not required to calculate EEDI values for both small vessels like tugs and yachts, it is highly recommended to use this index as a guide in assessing CO_2 emissions for these vessels.
- The EEDI for service ships like tugs and smaller vessels may be redefined to include Bollard Pull instead of weight transported.
- The attained EEDI can be improved through design hulls with less resistance, more efficient aft part and propeller arrangement. It is also possible to lower the attained EEDI with using engines that consumes less specific fuel consumption in addition to new types of fuels like natural gas, hydrogen and fuel cells.

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