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PREVENTION OF AIR POLLUTION FROM SHIPS

Influence of Design Parameters on the Energy Efficiency Design Index for Tankers, Containerships, and LNG Carriers

Submitted by the Institute of Marine Engineering, Science and Technology (IMarEST)

SUMMARY

Executive summary:	This document provides information on how design characteristics such as design speed, lightship, and the load line draught, influence the attained EEDI. Tankers, containerships and LNG carriers are analysed.
Strategic direction:	7.3
High-level action:	7.3.1
Planned Output:	7.3.1.3
Action to be taken:	Paragraph 27
Related documents:	MEPC.1/Circ.681, MEPC.1/Circ.684; MEPC 58/4/34; GHG-WG 2/2/7, GHG-WG 2/2/9, GHG-WG 2/2/22 and MEPC 59/4/20

Introduction and Background

1 This document is submitted in accordance with MSC-MEPC.1/Circ.2, Guidelines on the organization and method of work.

2 MEPC.1/Circ.681 on Interim Guidelines on the Method of Calculation of the Energy Efficiency Design Index for New Ships, has provided a core methodology for the calculation of a new vessel's attained EEDI. MEPC 59 has approved the use of the EEDI on a voluntary basis, and has invited feedback based on application of the interim Guidelines.

3 This document presents information from a study conducted for the Society of Naval Architects and Marine Engineers (SNAME) Technical & Research Program. The intent of the study is to provide a better understanding of the robustness of the EEDI in encouraging vessel optimization, and to determine whether development of baselines based on existing vessels with limited design data accurately reflects modern design practice. This document summarizes some

of the findings of that study relative to the effectiveness of the EEDI in encouraging design optimization, and also how changes in design characteristics impact the attained EEDI. Study reports developed by ABS and HEC on behalf of SNAME can be accessed on the SNAME website at: www.sname.org.

4 A parametric series of designs over a range of vessel sizes was developed for three ship types: oil tankers, containerships, and LNG carriers. Details on the ship characteristics, the calculation of the attained EEDI, and comparisons to the baseline curves presented in document GHG-WG 2/2/7 are provided to the Committee in document MEPC 60/4/33.

The influence of ship design speed on the EEDI

5 The EEDI is particularly sensitive to the service speed, as the required power increases by roughly the cube of the variation in service speed ($P \propto V^3$). As shown in Table 1, reducing service speed by one knot reduces the EEDI by between 10% and 15%.

Table 1: Influence of service speed on the EEDI

Tankers		-2 knots	-1 knots	Standard	+1 knots
Panamax	$EEDI_A$	4.33	5.16	5.95	6.82
	% Change	-27%	-13%	---	+15%
Aframax	$EEDI_A$	3.04	3.22	3.73	4.37
	% Change	-19%	-14%	---	+17%
Suezmax	$EEDI_A$	2.53	2.74	3.14	3.63
	% Change	-19%	-13%	---	+16%
VLCC	$EEDI_A$	2.10	2.24	2.53	2.87
	% Change	-17%	-11%	---	+14%

Containerships		-4 knots	-2 knots	Standard
1,000 TEU	$EEDI_A$	14.70	18.37	25.18
(Feedership)	% Change	-42%	-27%	---
4,500 TEU	$EEDI_A$	11.31	14.15	17.99
(Panamax)	% Change	-37%	-21%	---
4,500 TEU	$EEDI_A$	11.34	14.39	18.64
(Baby Neo-Panamax)	% Change	-39%	-23%	---
8,000 TEU	$EEDI_A$	10.53	13.07	16.17
(Post-Panamax)	% Change	-35%	-19%	---
12,500 TEU	$EEDI_A$	9.28	11.40	14.01
(Ultra Large)	% Change	-34%	-19%	---

LNG Carriers		-2 knots	-1 knots	Standard	+1 knots
150,000 m3	$EEDI_A$	4.46	5.03	5.93	7.16
DFDE - Single Screw	% Change	-25%	-15%	---	21%
180,000 m3	$EEDI_A$	4.17	4.70	5.59	7.01
DFDE - Single Screw	% Change	-25%	-16%	---	25%
215,000 m3	$EEDI_A$	3.88	4.49	5.28	6.67
DFDE - Single Screw	% Change	-27%	-15%	---	26%
180,000 m3	$EEDI_A$	5.04	5.79	6.68	7.73
DRL - Twin Screw	% Change	-25%	-13%	---	16%
215,000 m3	$EEDI_A$	4.69	5.40	6.23	7.20
DRL - Twin Screw	% Change	-25%	-13%	---	16%
265,000 m3	$EEDI_A$	4.43	5.09	5.87	6.78
DRL - Twin Screw	% Change	-24%	-13%	---	16%

DFDE – dual fuel diesel electric DRL – direct drive slow speed diesel and reliquefaction plant

The Influence of Summer Load Line Draught on the EEDI

6 Some designs such as large tankers and bulk carriers are typically deadweight limited and their summer load line draught is set at the maximum allowable value as dictated by the International Convention on Load Lines. However, other vessels such as containerships and LNG carriers are cubic volume limited. Their summer load line draught is set at a level above the design draught in order to accommodate heavier than normal cargoes, to allow for ballasting to deeper draughts to facilitate load/discharge operations, etc. Whereas increasing cargo capacity is a major cost to the shipbuilder/shipowner, increasing the load line draught generally involves minor changes to scantlings and a nominal increased cost of construction.

7 When increasing displacement, the relative increase in power will generally be smaller than the relative increase in displacement, other factors being equal. The principal particulars of the standard designs developed in this Study are based on regression analysis of recent newbuildings. These data indicate that the scantling draught/design draught ratio (Ts/Td) is about 1.12 for containerships and 1.08 for LNG carriers, although there is considerable scatter about these mean values. These ratios were applied to establish the load line draught for the standard designs. To gain an understanding of the impact of the selected load line draught on the EEDI, calculations were also run with Ts/Td=1.20 for containerships and Ts/Td=1.16 for LNG carriers.

8 Increasing the scantling draughts for containerships and LNG carriers in accordance with paragraph 7 reduced the EEDI as compared to the standard design by between 9% and 10%.

9 Thus, for certain designs, increasing the load line draught can significantly reduce the EEDI at little extra cost and with little or no impact on the expected fuel consumption. This is of concern, and suggests that the use of summer load line deadweight as a proxy for capacity needs further consideration. For LNG carriers, basing the EEDI on cargo cubic may be more appropriate and a better representation of the actual cargo carrying capacity of such vessels since increasing cargo cubic is expensive and could not be justified if done simply for the purpose of improving the EEDI. The capacity definition for containerships should be considered taking into account the findings of the Study.

The influence of hull steel weight on the EEDI

10 Concerns have been raised that the influence of hull steel weight on the EEDI may discourage introduction of more robust scantlings in future designs. It is also recognized that most of the existing fleet utilized to develop the EEDI proposed baseline were constructed prior to the implementation of the IACS Common Structural Rules (CSR) for tankers by the major classification societies. The CSR can add 3% to 8% to the hull steel weight.

11 To gain an understanding of the impact of increased steel weight on the EEDI, a 5% increase in hull steel weight was assumed for each of the standard designs. The block coefficient (Cb) was adjusted to maintain constant deadweight so the EEDI *Capacity* and therefore the EEDI baseline remained unchanged.

12 As shown in Table 2, a 5% increase in hull steel weight increases the attained index by between 0.5% and 1.4%. To put this in perspective, a speed reduction of between 0.05 and 0.10 knots would offset the impact of 5% increase in hull steel weight.

Table 2: Influence of hull steel weight on the EEDI

Tankers		Standard Design	5% added to Hull Steel
Panamax	Attained EEDI	5.95	6.03
	% Change vs. Standard Design	---	1.4%
Aframax	Attained EEDI	3.73	3.76
	% Change vs. Standard Design	---	0.8%
Suezmax	Attained EEDI	3.14	3.16
	% Change vs. Standard Design	---	0.7%
VLCC	Attained EEDI	2.53	2.54
	% Change vs. Standard Design	---	0.5%

Containerships		Standard Design	5% added to Hull Steel
1,000 TEU	Attained EEDI	25.18	25.39
(Feedership)	% Change vs. Standard Design	---	0.9%
4,500 TEU	Attained EEDI	17.99	18.14
(Panamax)	% Change vs. Standard Design	---	0.8%
4,500 TEU	Attained EEDI	18.64	18.81
(Baby Neo-Panamax)	% Change vs. Standard Design	---	0.9%
8,000 TEU	Attained EEDI	16.17	16.33
(Post-Panamax)	% Change vs. Standard Design	---	1.0%
12,500 TEU	Attained EEDI	14.01	14.17
(Ultra Large)	% Change vs. Standard Design	---	1.1%

Optimization of Principal Particulars

13 A series of parametric designs of aframax tankers were developed in order to evaluate the influence of variations in length, beam, depth, and Cb on the EEDI and CO_2 emissions. Designs covering a matrix of LBP/Beam and LBP/Depth ratios were considered, with the dimensions and block coefficient adjusted so that the cargo volume and deadweight were held constant.

14 The standard aframax tanker design has the following properties: LBP/Beam = 5.43 and LBP/Depth = 11.38. It was determined that improvements in the EEDI of 2% to 3% could be realized by increasing the LBP/Beam ratio to 6.0 and above and the LBP/Depth ratio to 12.5 and above. However, these small improvements in the EEDI come at a price, as construction cost increases, the vessel's length may exceed the berthing capability at many terminals, and the more flexible hull girder associated with the higher LBP/Depth ratios raises structural concerns. This study suggests that, although slightly longer ships with reduced block coefficient may be worth considering in the future, significant reductions in the EEDI are not possible through changes in particulars.

The EEDI and Optimization of Ship Designs

15 It should be recognized that by utilizing deadweight as a surrogate for Capacity, the EEDI does not encourage optimization through more effective utilization of the vessel, employment of larger vessels which benefit from economies of scale, and vessels specially designed for alternative backhauls. Rather, the EEDI may penalize such alternatives should they involve increased lightship weight or influence powering optimization.

16 Table 3 shows the expected EEOI (Energy Efficiency Operational Indicator) which is expressed in terms of CO_2 emissions per tonne-mile of cargo transport. A theoretical EEOI was developed assuming representative round trip voyages and estimated vessel manoeuvring and in-port emissions. This table illustrates the economies of scale offered by the larger vessels.

Table 3: Influence of ship size on CO_2 production

Tankers	Panamax Product 54,000 m^3	Aframax Crude 132,000 m^3	Suezmax Crude 180,000 m^3	VLCC Crude 360,000 m^3
EEOI g CO2 / tonne-nm	18.4	10.7	8.7	6.8

Containerships	Feedership 1000 TEUs	Panamax 4500 TEUs	Baby Neo-Panamax 4500 TEUs	Post-Panamax 8000 TEUs	Ultra Large 12500 TEUs
EEOI g CO2 / TEU-nm	578.3	434.4	382.0	317.6	280.5

LNG Carriers (DFDE Propulsion)	150,000 m^3 Single Screw	180,000 m^3 Single Screw	215,000 m^3 Single Screw
EEOI g CO2 / tonne-nm	29.7	27.2	25.6

LNG Carriers (DRL Propulsion)	180,000 m^3 Twin Screw	215,000 m^3 Twin Screw	265,000 m^3 Twin Screw
EEOI g CO2 / tonne-nm	35.1	33.5	31.3

A Comparative Analysis of Panamax Containerships

17 Panamax containership designs are another example of where the EEDI will not encourage optimization. Historically, the principal dimensions of containerships in the 3,500 to 4,500 TEU range have been adjusted from their optimum in order to allow transit through the Panama Canal. These designs have a length to beam ratio that does not enable efficient cargo stowage, and they must carry significant quantities of ballast water in order to maintain stability while maximizing cargo payload. An alternative design is the Baby Neo-Panamax containership which has an increased beam that allows for more efficient cargo stowage. The future expansion of the Panama Canal will allow the Baby Neo-Panamax containership to transit the canal.

18 To understand the impact of the shift from Panamax to Baby Neo-Panamax on the EEDI, standard designs of each class with similar displacements were analysed. Designs with a 4,500 TEU slot capacity were developed for comparison.

19 The decreased length to beam ratio of the Baby Neo-Panamax ship increases the power required to achieve the design speed. The increased power increases the EEDI of the Baby Neo-Panamax over the Panamax design by 3.6%.

Table 4: Influence of Panamax dimensions on the EEDI

		Panamax Design	**Baby Neo-Panamax Design**
Summer Load Line Draft	m	13.22	13.22
Deadweight at Load Line Draft	MT	58,817	60,747
Service Speed: 15% SM at 90% MCR	knots	24.50	24.50
Required Engine Power (MCR)	kW	38,532	41,330
Draft at 65% Summer Load Line Deadweight	m	10.30	10.27
Speed at 65%SLL DWT and 75% MCR (Vref)	knots	24.73	24.78
Attained EEDI ($EEDI_A$)		17.99	18.64

20 The EEDI does not take into account the amount of deadweight utilized by cargo as opposed to ballast water. Though the Baby Neo-Panamax design has a larger engine and therefore uses more fuel per nautical mile, the ratio of CO_2 to cargo carried is 12.6% lower as compared to the Panamax containership. The CO_2 to cargo carried data for an identical round trip voyage are shown in Table 5.

Table 5: Influence of Panamax dimensions on the EEOI

		Panamax Design	Baby Neo-Panamax Design
Total Cargo Carried	TEU	6,769	8,417
Total CO_2 Emissions	MT	8,576	9,376
CO_2 Emissions per Unit Cargo Carried	MT/TEU	1.27	1.11
EEOI	gCO2/TEU-nm	434	382

21 Thus, the EEDI considers that the Panamax design is a 3.6% better performer than the Baby Neo-Panamax design, whereas CO_2 emissions per unit mile (expressed in terms of the EEOI) are 13.8% higher for the Panamax design as compared to the Baby Neo-Panamax design.

Conclusions

22 This study demonstrates the high sensitivity of the EEDI to service speed.

23 Utilizing the deadweight at the summer load line draught as a proxy for cargo carried could lead to “gaming” of the EEDI by increasing the load line draught beyond current practice. At least for LNG carriers, cargo volume may be a better indicator of cargo-carrying capability.

24 Increasing steel weight by implementing more robust scantlings has a relatively modest impact on the EEDI.

25 Relatively little improvement in the EEDI can be achieved through adjustment of the main particulars (length, beam and depth) to minimize required power.

26 It should be recognized that the EEDI encourages optimization through improvements in hydrodynamic and aerodynamic performance and improvements in the power plant, but does not necessarily encourage the use of an optimized vessel for a given trade.

Action requested of the Committee

27 The Committee is invited to take note and consider the technical analysis described herein and take action as appropriate.

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