Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2012, 32(104) z. 1 pp. 102–107

2012, 32(104) z. 1 s. 102–107

The influence of chosen parameters on the Energy Efficiency Design Index

Tadeusz Szelangiewicz, Katarzyna Żelazny

West Pomeranian University of Technology in Szczecin, Faculty of Maritime Technology and Transport
71-065 Szczecin, al. Piastów 41, e-mail: tadeusz.szelangiewicz@zut.edu.pl

Key words: Energy Efficiency Design Index, ship speed, decrease of ship speed

Abstract
Since 2013 Energy Efficiency Design Index (EEDI) for new ships will be enforced. Ships meeting the CO_2 emission standards will be granted energy certificate required for their exploitation. The paper presents EEDI in the current form and influence of the ship speed and decrease of the ship speed on EEDI.

Introduction

Energy Efficiency Design Index (EEDI) published by IMO in 2009 (mandatory since 2013) will serve as monitoring tool for CO_2 emission per each tonne-mile of transported cargo by newly built / desined ships. The EEDI will be calculated according to the following formula (at present):

$$\frac{\prod_{j=1}^{M} f_j \left(\sum_{i=1}^{n\mathrm{ME}} P_{\mathrm{ME}(i)} C_{\mathrm{FME}(i)} \mathrm{SFC}_{\mathrm{ME}(i)} \right) + \left(P_{\mathrm{AE}} C_{\mathrm{FAE}} \mathrm{SFC}_{\mathrm{AE}} \right)}{f_i \cdot \mathrm{Capacity} \cdot V_{\mathrm{ref}} \cdot f_w} + \frac{\left(\prod_{j=1}^{M} f_j \left(\sum_{i=1}^{n\mathrm{PTI}} P_{\mathrm{PTI}(i)} - \sum_{i=1}^{n\mathrm{eff}} f_{\mathrm{eff}(i)} P_{\mathrm{AEeff}(i)} \right) C_{\mathrm{FAE}} \mathrm{SFC}_{\mathrm{AE}} \right)}{f_i \cdot \mathrm{Capacity} \cdot V_{\mathrm{ref}} \cdot f_w} + - \frac{\left(\sum_{i=1}^{n\mathrm{eff}} f_{\mathrm{eff}(i)} P_{\mathrm{eff}(i)} C_{\mathrm{FME}} \mathrm{SFC}_{\mathrm{ME}} \right)}{f_i \cdot \mathrm{Capacity} \cdot V_{\mathrm{ref}} \cdot f_w} \quad (1)$$

whose specific parameters have been presented in [1]. For each newly built ship, the calculated EEDI value will be compared against the so called "reference line" binding in 2013 and drafted up for specific types of ships. The reference line will be changing as to reduce CO_2 emission in subsequent years. The new ship will be awarded international energy certificate and fit to service when its EEDI value is equal or lower than the corresponding EEDI from the appropriate reference line. The analyses carried out mainly in 2011 have shown that the EEDI values of a number of ships currently in service approximate the reference line. It means that in some cases even a slight modification of ship service parameters, can result in EEDI decrease below the reference line. However, in the subsequent years when further CO_2 reduction will be required, achieving the appropriate EEDI value will, therefore, necessitate a more thorough approach – already at design and not only service stage. Thus, already at present further research in energy efficient ship design (and future limits on CO_2 emission) is very much needed. Significant potential in reducing the EEDI values can be defined as follows:

- improved hull design aiming at higher propulsion efficiency;
- more efficient propulsion engine – lower specific fuel consumption;
- higher fuel quality;
- development of new technologies, better waste heat recovery system;
- larger ship construction (bigger capacity);
- decreasing the ship's speed;
- optimalisation of the shipping route.

One of the essential ship service parameters, which also affect the EEDI value, is the ship's speed and its decrease while sailing on rough sea.

Ship speed

In the formula (1), there are given: service speed of a ship V_{ref} and f_w a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind (e.g. Beaufort Scale 6). Since both these values are in the denominator, the lower the service speed value V_{ref} together with higher f_w value (maximum $f_w = 1$), the lower the total EEDI.

The service speed V_{ref}, in present EEDI definition is the speed achieved at 75% MCR (Fig. 1), on calm sea and maximum capacity (65% capacity in case of container ships).

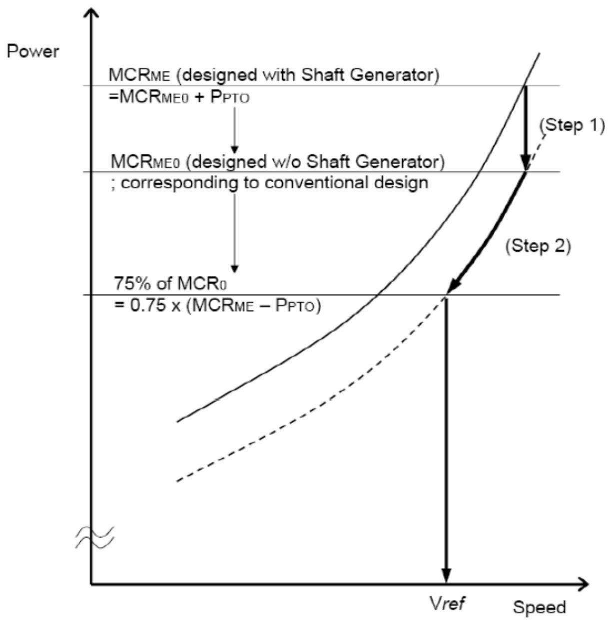


Fig. 1. Determining ship speed V_{ref} [1]

Since the ship speed V_{ref} is determined for a new ship, on deep water with no wind and wave action, hence in some publications it is equalled with contract speed V_C.

The power of the ship propulsion system is approximately dependent on ship speed cubed, hence every decrease of ship speed results in a major loss of the propulsion system and the EEDI value as well. For typical transport ships decreasing the ship speed by one knot results in 11–14% EEDI decrease (Fig. 2).

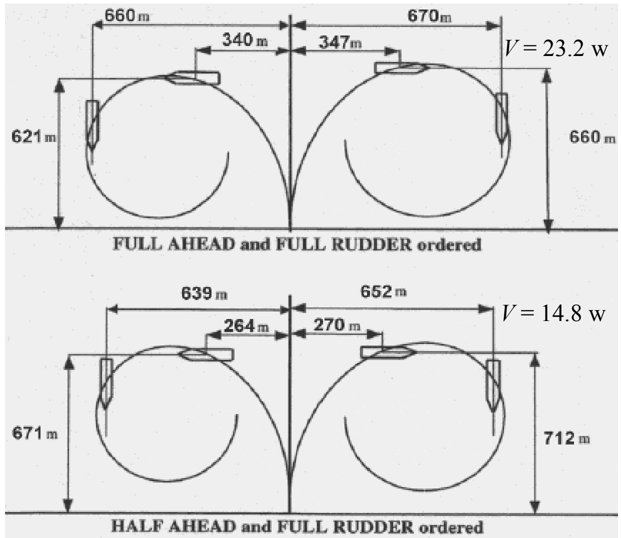
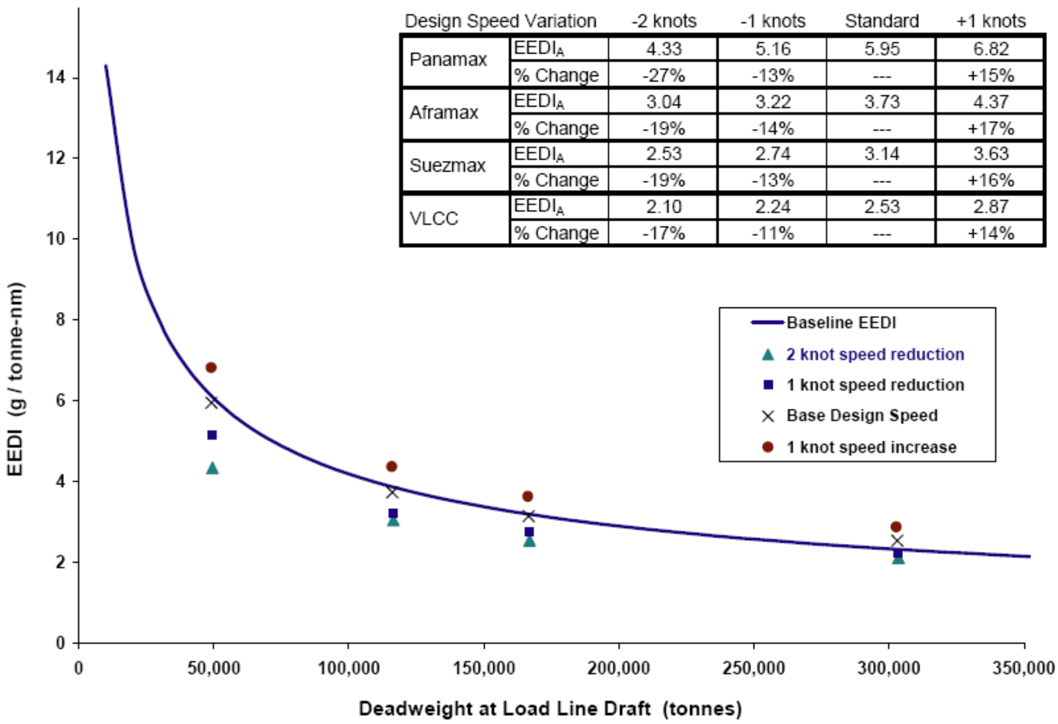


Fig. 3. The relation between the ship speed and circulation test [3]



Design Speed Variation		-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%

Fig. 2. EEDI of containerships with speed change [2]

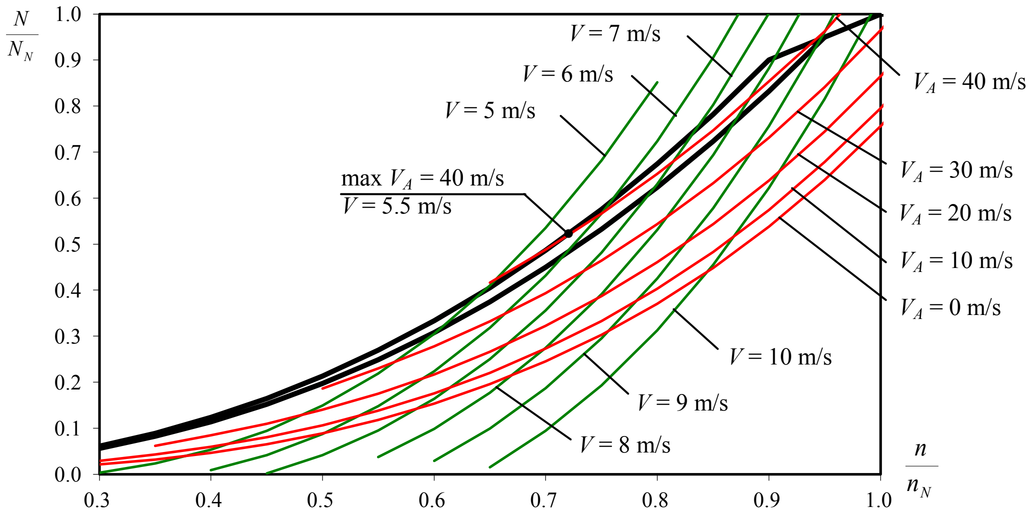


Fig. 4. Ship propulsion characteristics while sailing against the wind [4]: V_C = 8.44 m/s, V_A – average wind speed, V – ship speed while sailing against the wind

Decrease in ship speed, apart from the obvious longer sailing time of a ship, results also in:

- worse manoeuvrability, especially when apart from a plane ruder, the ship is not equipped with other steering devices such as e.g. bow tunnel thrusters [3];
- significant loss of safety while sailing against high opposite or oblique wave – the ship may lose its ability to move and stay on a set course [4].

Therefore, the IMO has published a guideline, specifically indicating that the potential ship speed reduction due to the EEDI value cannot lead to worsening of ship safety conditions.

Ship speed loss on rough sea

In the denominator of formula (1), there is a non-dimensional coefficient f_w indicating the decrease of speed in representative sea conditions of Beaufort Scale 6 [1]:

$$f_w = \frac{\text{ship speed in BF6}}{V_{\text{ref}}\,(\text{ship speed in calm sea})} \tag{2}$$

The f_w coefficient is not directly connected to engines or other equipment such as boilers consuming CO_2 fuel or even deadweight of a ship, still it plays a crucial role in calculation of EEDI and hence can be decisive whether or not a ship will be awarded energy efficiency certificate. It results from a fact that the f_w coefficient can assume value $f_w = 1.0$ (such value is suggested in [5] or lower, e.g. $f_w = 0.8$ [6]. Such difference in values can seriously affect the final EEDI value, therefore, the f_w coefficient should be calculated accurately and in a logically well – motivated way. As studies this area [7, 8] demonstrate, EEDI for many contemporary ships in use is very close to the stated reference line.

One of the methods to calculate the f_w coefficient, given in [1], is the assumption that the ship is acted upon by waves and wind speed at BF6. The direction of wind and wave is not given, it is commonly assumed that the ship is sailing against wind and waves. While an average wind speed at BF6 can be determined, the wave height at such speed can vary on different sea areas. Therefore, such calculation method of f_w coefficient is inaccurate, since in real sea conditions, geographical directions of wind and waves and their parameters (wind speed, wave height and period) are changeable, while ships sail different courses against the waves on different routes across different sea areas. Currently, a number of calculation methods of f_w coefficient are being discussed, with several proposals suggested by various countries [6, 7, 12] which indicate the prime importance of this issue.

The article presents a new method of calculation of f_w coefficient, which assumes that:

- a ship can sail different courses on different routes crossing different sea areas;
- there are mean long-term statistical values of wind and waves (together with the probability of their occurrence) present on those different sea areas.

Loss of ship speed calculated in this way will also be a mean long-term statistical value for a selected shipping route or a mean value for numerous shipping routes.

In order to calculate mean speed loss of a ship in real weather conditions occuring on a given shipping route, we first need to obtain a mean statistical value of the f_w coefficient:

Table 1. Ship parameters

Data \ Ship	Symbols	Container ship			Bulk carrier			
		K1	K2	K3	M1	M2	M3	M4
Lenght between perpendicular	L [m]	140.14	171.94	210.20	138.0	185.0	175.6	240.0
Displacement	∇ [m^3]	17300	29900	47250	21441	40831	56396	73910
Calm-sea speed of a ship	V_{Ref} [m/s]	8.44	9.62	10.80	7.15	7.72	8.2	8.28
Service margin assumed in a ship propulsion design	$k_ż$ [%]	15	15	15	15	15	15	15

$$\bar{f}_w = \frac{\bar{V}_E}{V_{\text{ref}}} \tag{3}$$

where: V_{ref} is sheep speed on calm sea, and $\bar{V}_E$ – mean statistical service speed of a ship under mean statistical weather conditions on a given shipping route.

A detailed account of the calculation method presented here, has been given in [4].

Mean, statistical value of the f_w coefficient – an example of calculations

Calculation of the mean statistical value of f_w coefficient has been performed for transport ships (Table 1) and selected seasonal shipping routes (Table 2).

Table 2. Specification of the shipping routes used for the calculation of the additional resistance and service speed of a ship

No.	Name
1	South America – West Europe
2	US East coast – West Europe
3	US East coast – Gulf of Mexico – West Europe
4	US East coast – Mediterranean – West Europe
5	Indonesia – Japan
6	Persian Gulf – Japan
7	North Africa – West Europe
8	North Africa – US East coast.
9	Persian Gulf – Africa – West Europe
10	West Europe – Mediterranean – Persian Gulf – Japan
11	West Europe – Panama Canal – US West coast
12	West Europe – Latin America

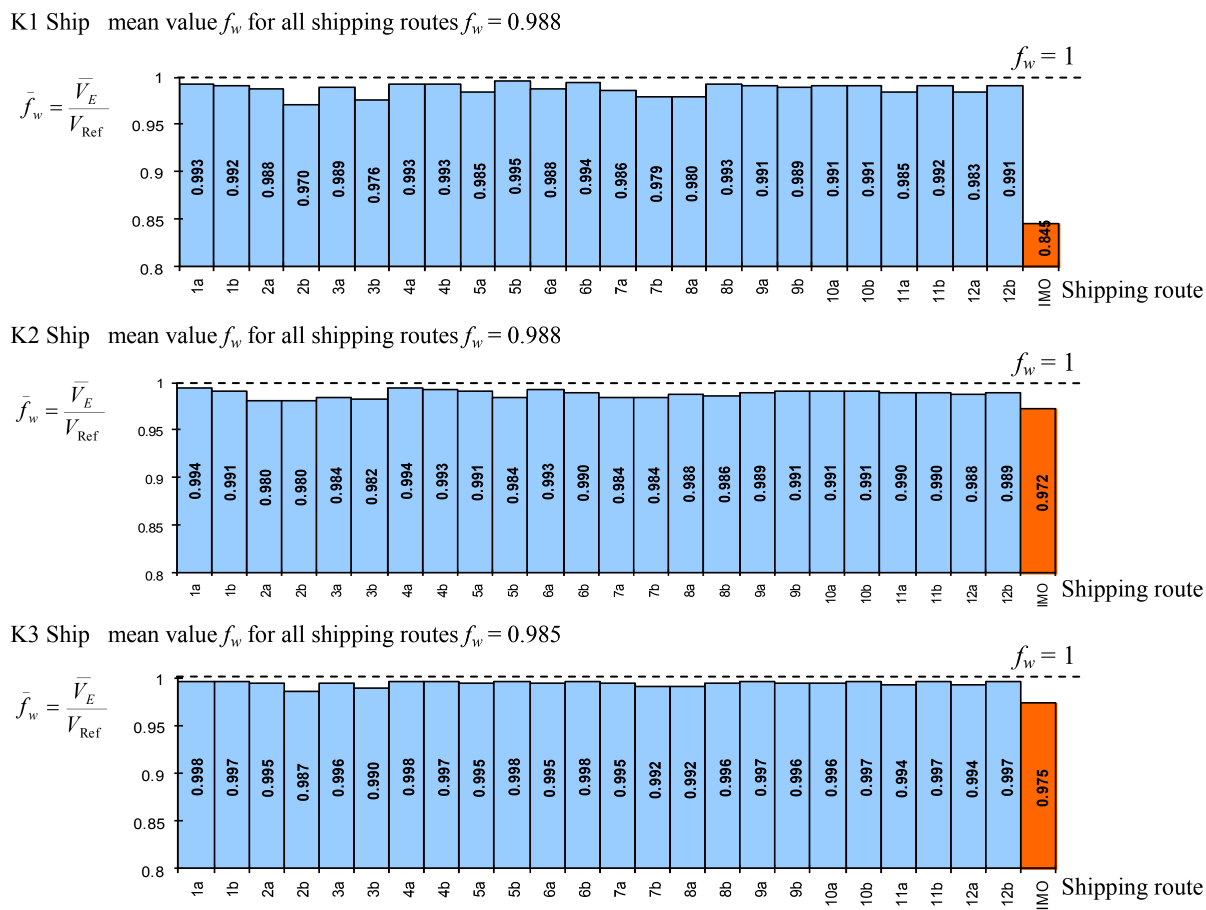


Fig. 5. Coefficient $\bar{f}_w$ for tested containerships and selected shipping routes

Calculation results for the f_w coefficient

For each shipping route (index „a" respresents one-way voyage of a ship while "b" – return) running across specific sea areas, probabilities f_A, f_S have been determined, while probabilities f_μ and f_{HT} have been taken from the wave statistics [11, 12]. Probablilties f_V and f_ψ – have been determined on the basis of a selected shipping route of a ship. For each ship and shipping route histograms and distribution function of additional resistance and ship service speed have been calculated first, and then – mean statistical speed values, as well as the $\bar{f}_w$ coefficient. An example of these calculations is shown in figures 5 and 6.

Conclusions

The EEDI formula (1) can be still amended, since there have been ongoing calculatory analyses with resulting suggestion as to change some of the coefficients, their interpretation or calculation methods.

Some of the parameters, present in the formula (1), have a major influence on the calculated EEDI value. The paper has shortly presented the relation of EEDI and ship speed, marked as V_{ref} in the EEDI formula, and the loss of this speed on rough sea (f_w coefficient).

The EEDI value is influenced also by some other parameters, which can be calculated in

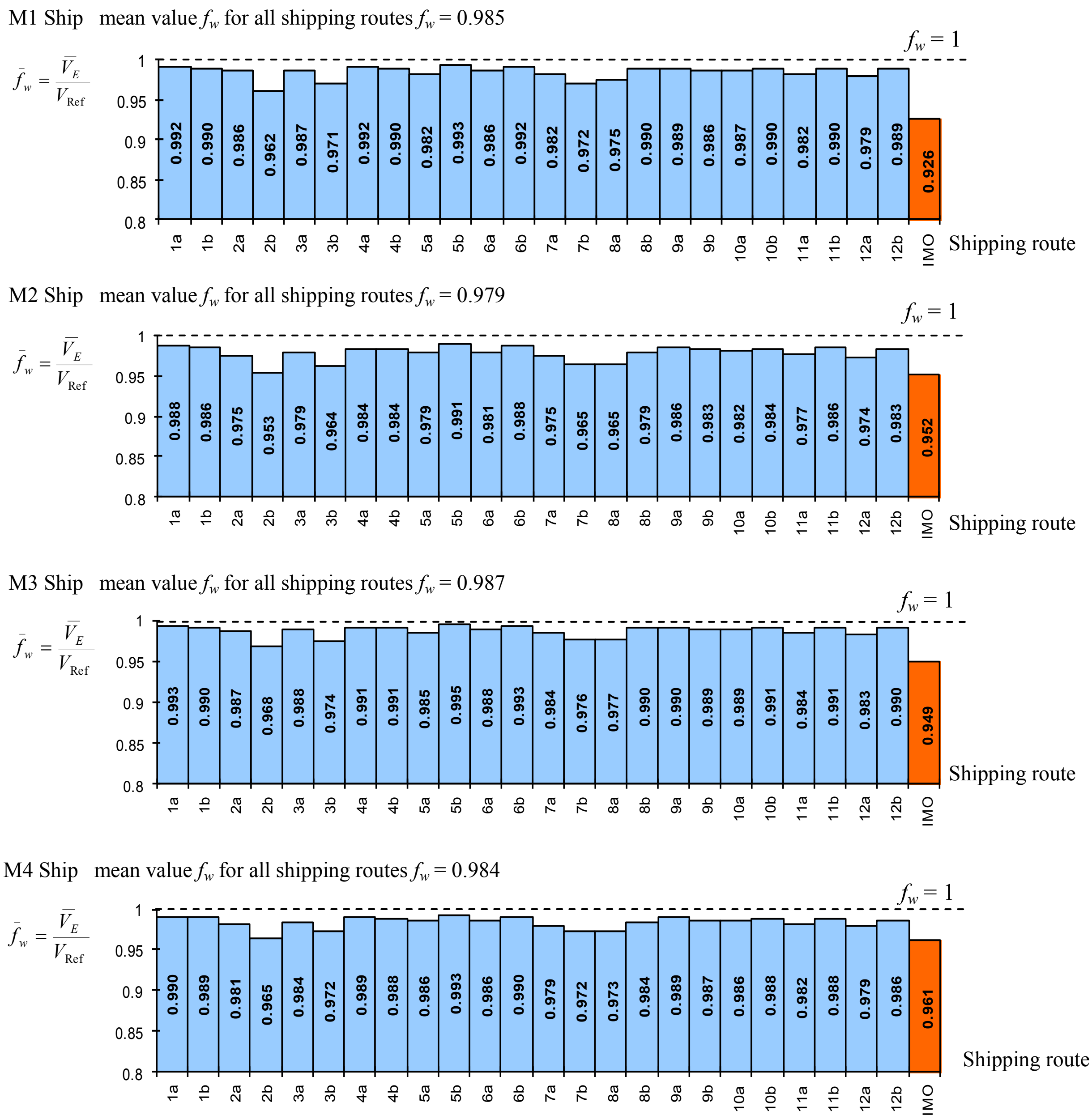


Fig. 6. Coefficient $\bar{f}_w$ for tested bulk carriers and selected shipping routes

numerous ways. It means that already at the initial stages of ship design, its parameters can be adjusted in such way as not only to meet the requirements of a ship owner (e.g.: ship capacity and speed), but also achieve the EEDI value required for the international energy efficiency certificate.

References

1. MEPC.1/Circ.681, Interim Guidelines on the Method of Calculation of the Energy Efficiency Design Indes for New Ship's", 2009.
2. OZAKI Y., LARKIN J., TIKKA K., MICHEL K.: Influence of Design Parameters on the Energy Efficiency Design Index (EEDI) Baseline. ABS, 2010.
3. SINGH S., PAROLCZYK J., ŁUKASZEWICZ A., WOŹNICA S.: Dobór prędkości bezpiecznej statku do przewozu kontenerów IV generacji na torze podejściowym do portu Gdynia. Prace Wydziału Nawigacyjnego, Nr 17, Akademia Morska w Gdyni, Gdynia 2005.
4. ŻELAZNY K.: Numeryczne prognozowanie średniej, długoterminowej prędkości eksploatacyjnej statku transportowego (Numerical prediction of the mean long-term service speed of a transport ship). PhD thesis, Westpomeranian of Technology in Szczecin, Faculty of Maritime Technology and Transport, Szczecin 2005.
5. MEPC 61/5/16, Consideration of the EEDI for new ships. A proposal on removing the coefficient f_w from EEDI formula, submitted by China, 2011.
6. MEPC 62/5/24, Proposal to modify the definition of container ships for EEDI calculation, submitted by Republic of Korea, 2011.
7. Study on tests and trials of the Energy Efficiency Design Index as developed by the IMO, Report for project 6543, Deltamarin Ltd, Finland 2011.
8. OZAKI Y., LARKIN J., TIKKA K., MICHEL K.: An Evaluation of the Energy Efficiency Design Index (EEDI) Baseline for Tankers, Containership, and LNG Carriers. ABS, 2010.
9. MEPC 61/5/21, Comments of the draft guidelines on the method of calculation of the attained EEDI for new ships, submitted by Greece, 2010.
10. MEPC 62/5/3, Treatment of coefficient f_w in the EEDI and the guidelines for the simulation of ship performacne to obtain coefficient f_w, submitted by Japan, 2011.
11. HOGBEN N., DACUNHA N.M.C., OLLIVER G.F.: Global Wave Statistics, BMT, 1986.
12. HOGBEN N., LUMB F.E. Ocean Wave Statistics, National Physical Laboratory, London 1967.