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REDUCTION OF GHG EMISSIONS FROM SHIPS

Consideration of the Energy Efficiency Design Index for New Ships

Minimum propulsion power to ensure safe manoeuvring in adverse conditions

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SUMMARY

Executive summary:	This document provides further information on the proposed draft interim guidelines to determine whether available propulsion power is sufficient to enable safe manoeuvring in adverse conditions in the context of the EEDI framework. It also provides an example on the simplified assessment proposed therein for verification in the initial phase.
Strategic direction:	7.3
High-level action:	7.3.2
Planned output:	7.3.2.1
Action to be taken:	Paragraph 4
Related document:	MEPC 62/5/19

Introduction

1 At MEPC 61, one of the focuses on safety implications relating to EEDI was a ship's manoeuvrability in adverse conditions. As proposed by IACS, and accepted by the Committee, a statement was added to the draft regulation text to require ships to maintain manoeuvrability under adverse conditions based on guidelines to be developed by the Organization. For this purpose, document MEPC 62/5/19, providing the draft interim guidelines, was submitted to the Committee. Document MEPC 62/5/19 also describes the challenges in developing such guidelines and proposes that a 2-phase approach be adopted. The first phase would utilize a simplified assessment. Depending on the experience gained in the first phase, a second phase utilizing more comprehensive assessment may be considered subject to availability and practicability of tools.

The interim guidelines

2 A goal-based approach was used for the development of the interim guidelines. While the goal, functional requirements, acceptance criteria and verification procedures have been identified and described in the annex to document MEPC 62/5/19, the methodology for setting the acceptance criteria remains an area of research. In this regard, and to assist in further research, the work undertaken thus far is provided at annex 1 to this document.

3 Due to the complexity of this issue, and associated verification procedures, a simplified approach is proposed in document MEPC 62/5/19 for use in the interim. This simplified approach requires the verification of advance speed of the ship under defined head sea and wind condition only. An example of this approach is provided at annex 2 to this document.

Action requested of the Committee

4 The Committee is invited to note the information provided above and in the attached annexes.

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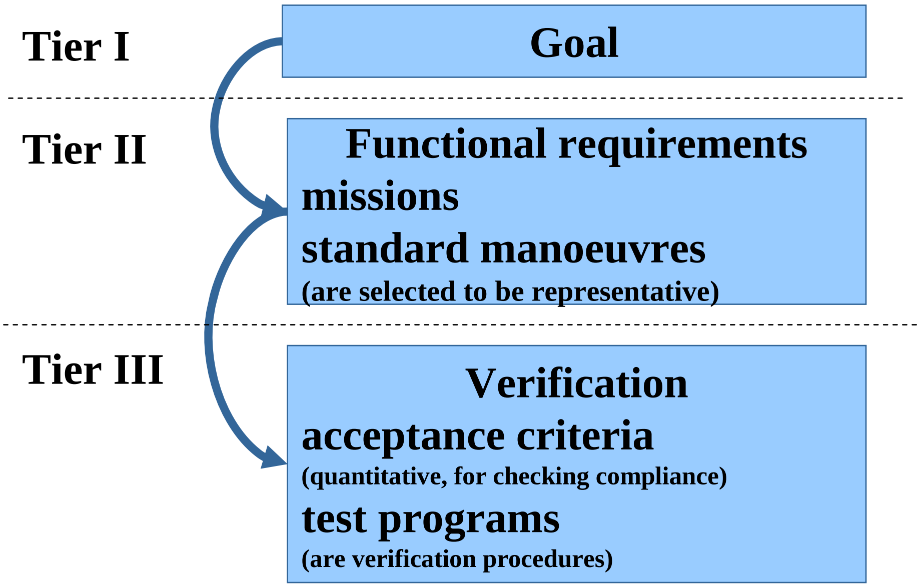
ANNEX 1

BACKGROUND TO DRAFT INTERIM GUIDELINES

General

1 The draft interim guidelines were written following the draft generic guidelines for developing IMO goal-based standards (GBS) contained in the annex of document MSC 87/5. The following figure shows the structure of the draft interim guidelines and its elements, which closely follow the general hierarchy of the GBS.



Assumptions

2 Current manoeuvrability standards at IMO are seen as a lower bound to the requirements on manoeuvrability in adverse conditions. However, the current level of manoeuvrability in adverse conditions has never been checked and is not explicitly known. Therefore, it may be possible that existing vessels will be identified to be "underpowered" when the newly proposed assessment is applied for test purposes.

3 As part of the work, IACS developed a draft questionnaire to guide interviews with masters of typical merchant vessels. The purpose of these interviews was to identify events which masters associate with adverse conditions and to learn more on best practices in such conditions. The interview campaign was performed asking a small number of masters and chief officers with more than 15 years of professional experience and active on all types of vessels. Their responses were mostly used to select the environmental conditions.

4 In adverse conditions, masters voluntarily reduce speed to decrease ship motions and, thus, to avoid damages to the ship and its cargo. In addition, added resistance in waves slows down the vessel. Lower ship motions also contribute to better manoeuvrability with higher forces on the rudder. In addition, existing rules (e.g., on lashing) assume that the master has the ability to avoid adverse conditions and to control ship motions. Therefore, too extreme environmental conditions for testing manoeuvring capability may be inconsistent with existing rules.

Goal

5 In recent debate at IMO, IACS's proposal to add a provision to the draft regulations text (MEPC 61/5/32) was agreed to and incorporated as Regulation 21.4 (see, e.g., Circular letter No.3128):

> "*For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions as defined in the guidelines to be developed by the Organization*."

6 An IACS project team then formulated the performance goals reflecting the above and defined the high level objectives for safe manoeuvring in adverse conditions.

7 It is noted that propulsion power alone is not sufficient to guarantee safe manoeuvring in adverse conditions. An effective rudder is also needed. At this stage it is assumed that required rudder performance as specified in resolution MSC.137(76) and MSC/Circ.1053 is sufficient and no additional requirement is considered.

8 Since the required level of safety for manoeuvrability in adverse conditions is not defined today, as a starting point, casualty reports from the IHS database have been checked to identify the frequency of occurrence of grounding events in adverse conditions.

9 Casualty reports after 1981 for bulk carriers, container vessels, general cargo ships and tankers built after 1981 with a minimum gross tonnage of 1,000 were selected when the accident severity was labelled "serious". Casualties which may have been caused by lack of available propulsion power in adverse conditions were identified as grounding accidents in adverse conditions without any cause listed (which means that lack of propulsion power could have been the case). This resulted in 64 events in open sea conditions. The following table shows the identified events and event frequencies. It is clear from this first review that general cargo vessels have the highest frequency for such events, followed by bulk carriers and tankers.

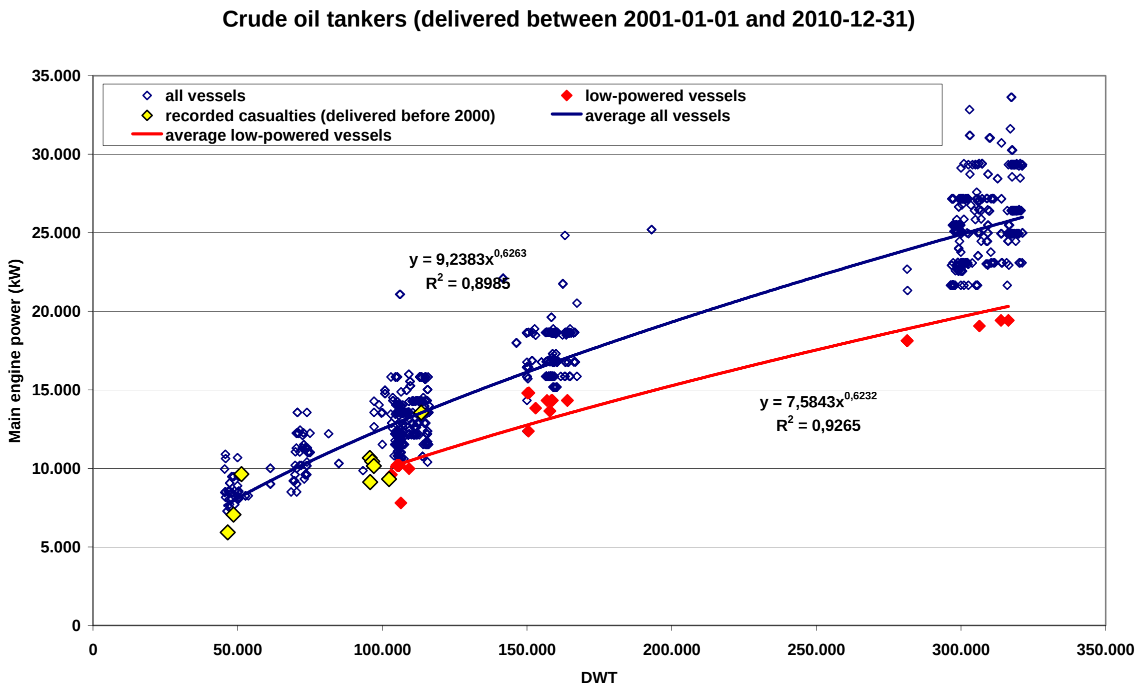
Ship type	Number of events.	estimated ship years	frequency
Bulk carrier	19	187050	1,02E-04
Container vessel	6	131080	4,58E-05
General cargo ship	27	194851	1,39E-04
Tanker	12	118204	1,02E-04
Total	64	631185	1,01E-04

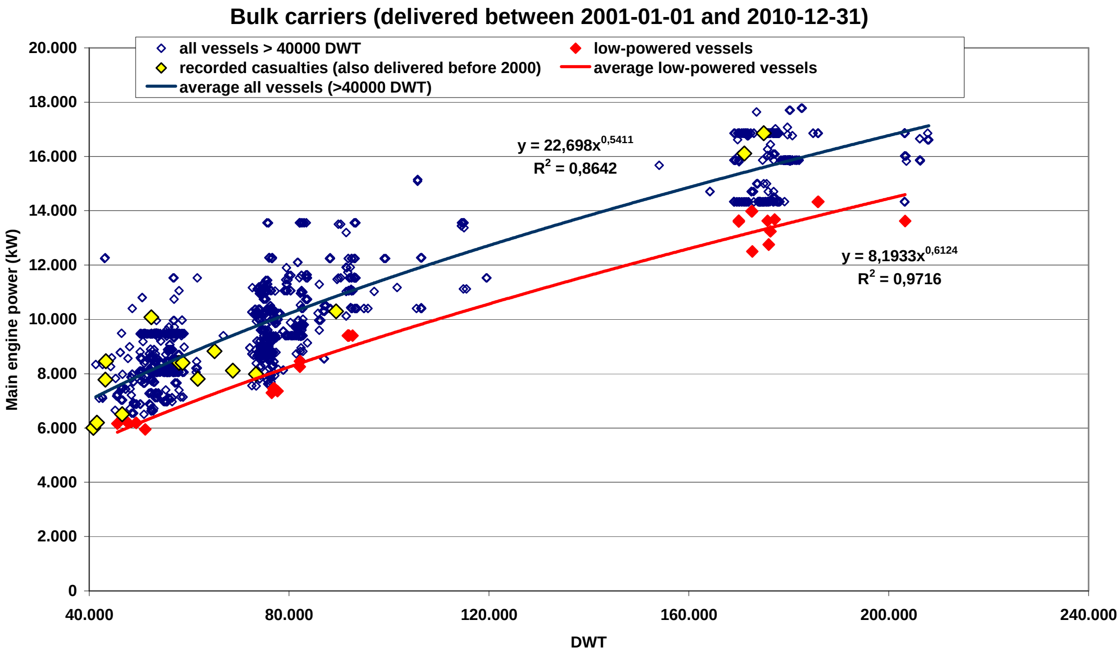
10 Another approach to identify the current state of installed power and potential link with lack of available propulsion power in adverse conditions is built on the idea that vessels having less than average installed power may be susceptible to incidents due to manoeuvring capability in adverse conditions. As example, bulk carriers and oil tankers built in the last decade and larger than 40,000 DWT were analysed and the vessels with lowest installed power were visually selected. These low-powered vessels have significantly lower installed power compared to the fleet average. A cross-check of casualty information with ship data showed that:

.1 Involved tankers were small and medium-sized tankers up to Aframax size. They have all been more than 10 years in service and had less-than average installed power, see figure below. No casualties have been recorded in this context for tankers of Suezmax size or for VLCCs.

.2 Involved bulk carriers were mostly small and medium sized. Most have been more than 10 years in service. However, no clear trend emerged regarding their installed power, see figure below. In particular, the two largest bulk carriers involved in groundings with heavy weather had more than average installed power.

11 This first analysis shows that smaller vessels have a higher probability for "grounding in heavy weather" with 37% of bulk carriers and tankers smaller than 40,000 DWT, and another 39% between 40,000 DWT and 80,000 DWT, and only 24% larger than 80,000 DWT.





Functional requirements

12 Functional requirements provide the criteria to be satisfied in order to meet the goals. Five missions (open sea transit, restricted navigation-space operation, rescue operation, towing operation and port operation) were identified and required manoeuvres were listed. It became clear that operation in restricted navigation space dominates the other missions. In other words, a vessel capable of manoeuvring safely with restricted navigation space, which involves potentially also unfavourable headings, is assumed to be able to master the other missions, too.

13 One exemption is the operation in port which is assumed to be assisted by tugs and, therefore, is not considered any further in this context.

14 Necessary manoeuvres involve course keeping, track keeping, turning, propulsion, stopping, keep heading, station keeping. In the next step, standard manoeuvres were defined to reflect all required manoeuvring capabilities. Eventually, only two standard manoeuvres were identified to be representative for the manoeuvrability of a vessel in adverse conditions and reflecting the defined missions: turning ability and course keeping with advance speed.

15 It is underlined that it was always the aim of the IACS project team to consolidate the number of manoeuvres such that resulting standard manoeuvres can be checked with reasonable effort.

Verification – acceptance criteria

16 To check whether a vessel is capable of successfully performing a standard manoeuvre, quantitative acceptance criteria were defined relating to each standard manoeuvre. It is noted that the figures given are suggestions by IACS and these need to be validated using expert opinion, numerical simulation and/or model experiments before being agreed by the Committee. And all figures need to be consistent with each other.

17 The turning ability is described by the time needed and the advance distance. Both criteria reflect the need to manoeuvre safely even with restricted navigation space. It is expected that the maximum time allowed for turning may also depend on ship size. Results from interviews also underline that time for action is limited to a few hours if the vessel is close to coast. If the vessel is on anchorage, it takes up to 1.5 hours to lift the anchor and to start picking up minimum speed.

18 The course keeping and advance speed capability is described by the minimum speed through water and the average static course deviation. Setting the minimum speed in this context is essential as it affects setting the other parameters as well. It was considered that a vessel needs to leave the coast by a couple of miles in few hours aiming to have more navigation space and then being able to turn the vessel into more favourable heading.

19 Results from interviews with experienced masters showed that they reduce speed up to a minimum to avoid damages to the hull and cargo. This minimum speed for adverse conditions has been stated to be between 4 knots, which is considered to be the minimum needed to ensure manoeuvrability, and up to 8 knots for a large container vessel.

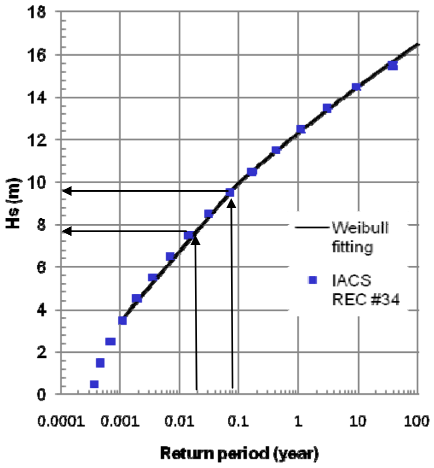
20 The environmental conditions to be considered were selected based on the widely accepted IACS wave data (IACS Recommendation 34), mainly because these North Atlantic environmental conditions are used as reference in the IMO GBS on oil tankers and bulk carriers. This means that wave conditions were identified based on their probability and that related wind conditions were set independently.

21 Adverse environmental conditions were selected based on assumed reasonable probability levels, results from interviews with masters and one accident report. Probability levels of 2% to 0.5% corresponding to return periods of 1 week to 1 month appear reasonable. A wave height of 8 metres and a wind force Beaufort force 9 were considered to be adverse conditions for a large tanker by experienced masters. And sea states 7 to 8 were recorded in the Pasha Bulker casualty report. In these conditions, many vessels safely manoeuvred and, therefore, these conditions can be assumed to be adverse but not overwhelming.

> "*On 8-9 June, 2007, the adverse condition with wind up to storm force (Beaufort force 10) occurred off the coast near Newcastle, Australia. There were 41 ships anchoring at the port area during the adverse condition. A number of ships attempts to ride out the adverse condition and the majority dragged their anchors. The substantial ship queue increased the risks in the anchorage and resulted in one ship grounding (Pasha Bulker), another near grounding, a near collision, and a number of close-quarters situations at the time. At the end, 40 ships managed to weight anchors or cut anchors and put to sea. This case provides the evidence that the installed power and rudder on these ships are sufficient to successfully manoeuvre in the adverse condition, which is close to North Atlantic conditions with a return period between one week and one month and defined by sea state 7 to sea state 8. On the other hand, it also provides the evidence that the defined adverse condition is actually occurring close to coast.*" Reference: Australian Transport Safety Bureau, June 2007, Marine occurrence investigation No. 243

22 Therefore, a range of environmental conditions assumed to be representative for adverse conditions is offered for discussion. They differ in their probability of occurrence, or return period, see figure below:

IACS Rec No 34 wave height vs return period



23 Sea state 8 is seen as on the edge towards extreme conditions and smaller vessels might be overwhelmed already. The lack of manoeuvring performance for particular vessels in extreme conditions is known to their masters and they aim at avoiding these situations. For example, a fully loaded container vessel will not be able to turn against extreme wind forces. This could potentially lead to setting different environmental criteria for different ship types and/or sizes which was, however, not considered in the current proposal due to a lack of evaluation results for different ship types and sizes.

24 For vessels with restricted navigation, environmental conditions need to be adapted taking operational area and restrictions into account.

Verification

25 Two verification approaches have been identified. These differ in their complexity and necessary resources. Test programs describe in detail which tests should be performed. Since no full scale tests can be performed, either model experiments and/or numerical simulations need to be conducted according to the test programs.

26 Test programs describe all necessary conditions for conducting the tests, such as, e.g., loading condition, engine and rudder settings, wind force and directions, wave height, periods and directions as well as the assessment parameters which directly relate to the acceptance criteria. In addition, a proposal to evaluate uncertainty from results in irregular waves is made.

27 Criteria to decide whether an individual vessel may be assessed with the simplified advance speed assessment have been identified and these relate to ship speed and to windage effect which is proportional to the ratio of above waterline lateral area and below waterline lateral area. The quantitative values for the criteria have not been finalised. Indeed, it is suggested to consider using the advance speed assessment for all ships in a first phase to gain experience, before switching to the more difficult but comprehensive assessment.

28 The basic assumption for the advance speed assessment is that the dimensioning criterion is advance speed in waves and, implicitly, that turning and course keeping can be achieved if advance speed is maintained. This assumption is true for typical bulk carriers and oil tankers but may be questioned for fully loaded container vessels which are known to have reduced manoeuvring capability in strong gale force winds. However, it is assumed that due to their relatively high installed engine power, the impact of the EEDI would not lead to negative effects on safety too soon. The latter assumption needs to be checked for vehicle carriers, ferries and cruise vessels.

29 This simplified assessment comprises only the equation of steady motion in longitudinal direction and tools are available today to make it work. A worked example for the advance speed assessment is contained in annex 2 for a VLCC in fully loaded condition, acknowledging the uncertainties involved. Forces include calm water hull resistance, rudder resistance, air drag, and added resistance in waves. All terms may be approximated by simple formulae or using tabulated values or simple model tests.

30 The comprehensive assessment following the full draft interim guidelines require many more tests to be performed and, therefore, they are considered not to be practical today. They may also be used to guide rule-making. This would require a larger number of numerical simulations per ship type with a number of ship sizes. Regression formulae may yield the desired trends for manoeuvrability as function of main ship parameters. However, the eventual success of this exercise was questioned by experts and, therefore, is not guaranteed.

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ANNEX 2

EXAMPLE FOR ADVANCE SPEED ASSESSMENT[1]

Preamble

1 This example is intended for illustration of the method of calculations only using a hypothetical ship, and as such, the numerical values therein should, in no way, be interpreted as representative of the criteria set out in the interim guidelines described in document MEPC 62/5/19.

Introduction

2 The basic assumption of this simplified assessment is that the dimensioning criterion is advance speed in waves and, implicitly, that turning and course keeping can be achieved if advance speed is maintained. This simplified assessment comprises only the equation of steady motion in longitudinal direction. It is only applicable to vessels below a Froude number and below a lateral area ratio given in the guidelines.

Procedure

3 The principle of the assessment is that the required propeller thrust, defined as a sum of bare hull resistance in calm water R_{cw}, resistance due to appendages R_{app}, aerodynamic resistance R_{air}, and added resistance in waves R_{aw},

$$T = R_{\mathrm{cw}} + R_{\mathrm{air}} + R_{\mathrm{aw}} + R_{app}, \qquad (1)$$

can be provided by the vessel's propulsion system.

4 The calm-water resistance can be calculated neglecting the wave resistance as $R_{\mathrm{cw}} = (1+k)C_F \frac{1}{2}\rho S v_s^2$, where k is the form factor, $C_F = \frac{0.075}{(\log \mathrm{Re} - 2)^2}$ the friction resistance coefficient, $\mathrm{Re} = v_s L_{pp} / \nu$ is the Reynolds number, ρ is water density, S is the wetted area of the bare hull, v_s is the ship speed and ν is the kinematic density of water.

5 Aerodynamic resistance can be calculated as $R_{\mathrm{air}} = C_{\mathrm{air}} \frac{1}{2} \rho_{\mathrm{a}} A_{\mathrm{F}} v_{\mathrm{w}}^2$, where C_{air} is the aerodynamic resistance coefficient, ρ_{a} is the density of air, A_{F} is the frontal projected area of the hull and v_{w} is the relative wind speed.

6 The added resistance in waves R_{aw} can be derived from model tests, potential or viscous flow computations or empirical formulae.

7 In order to check whether the required thrust can be provided by the engine, the required advance ratio of the propeller J is found from the requirement

$$T = \rho u_{\mathrm{a}}^2 D_{\mathrm{P}}^2 K_{\mathrm{T}}(J) / J^2, \qquad (2)$$

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[1] This example for an advance speed assessment was prepared by Germanischer Lloyd.

where $K_T(J)$ is the thrust coefficient curve. After this, the required rotation speed of the propeller is found from the relation

$$n = u_a / (JD_P), \tag{3}$$

and the required power is then defined from the relation

$$P_D = 2\pi\rho n^3 D_P^5 K_Q(J). \tag{4}$$

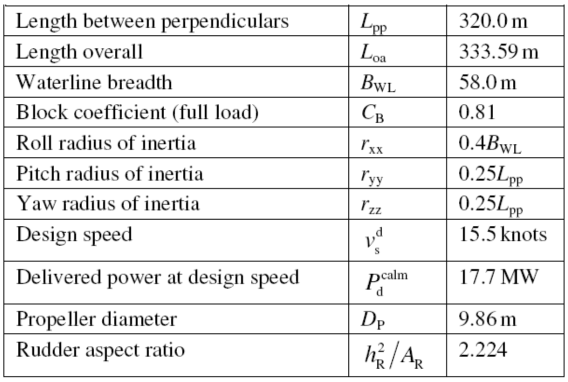
8 It should be noted that for diesel engines, the available power is also limited due to the torque-speed limitation of the engine $Q \le Q_{max}(n)$, thus an additional requirement to be checked is

$$Q = P_D / (2\pi n) \le Q_{max}(n). \tag{5}$$

Example of Simplified Assessment

9 The proposed procedure is applied to the tanker KVLCC2 at full load which has been widely tested before in calm water manoeuvring tests and benchmarking exercises (http://www.simman2008.dk). The main data is shown in the following two tables:

Main particulars and loading conditions for test vessel KVLCC2



Length between perpendiculars	L_{pp}	320.0 m
Length overall	L_{oa}	333.59 m
Waterline breadth	B_{WL}	58.0 m
Block coefficient (full load)	C_B	0.81
Roll radius of inertia	r_{xx}	$0.4B_{WL}$
Pitch radius of inertia	r_{yy}	$0.25L_{pp}$
Yaw radius of inertia	r_{zz}	$0.25L_{pp}$
Design speed	v_s^d	15.5 knots
Delivered power at design speed	P_d^{calm}	17.7 MW
Propeller diameter	D_P	9.86 m
Rudder aspect ratio	h_R^2/A_R	2.224

	Full Load	Heavy Ballast	Light Ballast
Draught midship T_m, m	20.8	10.0	8.0
Displ. volume V, m^3	$3.126 \cdot 10^5$	$1.236 \cdot 10^5$	$1.099 \cdot 10^5$
Long. distance of CG from AP, m	171.20	171.613	176.27
Mass, t	$3.200 \cdot 10^5$	$1.267 \cdot 10^5$	$1.127 \cdot 10^5$
Projected frontal area A_F, m^2	1356.7	1651.0	1767.0
Lateral area A_L, m^2	4005.7	6593.0	7260.2
Projected rudder area A_R, m^2	122.9	84.6	61.6

Parameter	***Definition***	***Source***	***Value Used***
A_{F}	projected frontal area	ship data	1356.7 m^2
S	submerged surface area of bare hull	ship data	27457.7 m^2
C_{air}	coefficient of aerodynamic resistance	wind tunnel test, RANSE simulation or empirical formulae	1.0
D_{P}	propeller diameter	ship data	9.86 m
k	form factor	model tests, viscous flow calculations, empirical formulae	0.22
$K_T(J)$, $K_Q(J)$	propeller curves	open-water propeller tests, propeller series, numerical calculations	Fig. 1
$Q_{\max}(n)$	engine torque/speed limiting curve	engine passport	Fig. 2
v_{s}	ship speed	assessment requirement [3.0 knots]	1.543 m/s
v_{w}	relative wind speed	sum of wind speed [51.5 knots] and ship speed [3.0 knots]	28.0 m/s
w	propeller wake fraction	model tests, viscous flow calculations, empirical formulae	0.4
ρ	density of water		1025.0 kg/m^3
ρ_{a}	density of air		1.2 kg/m^3

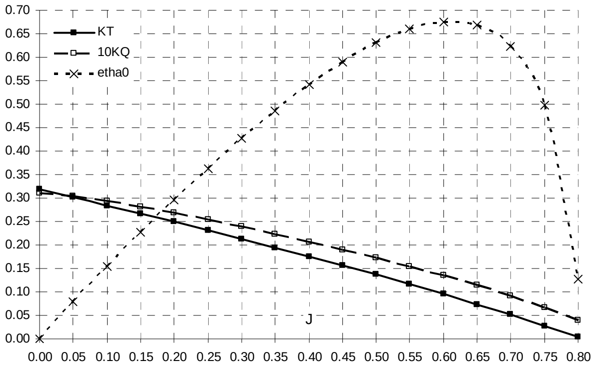


Fig. 1. typical open-water propeller curves

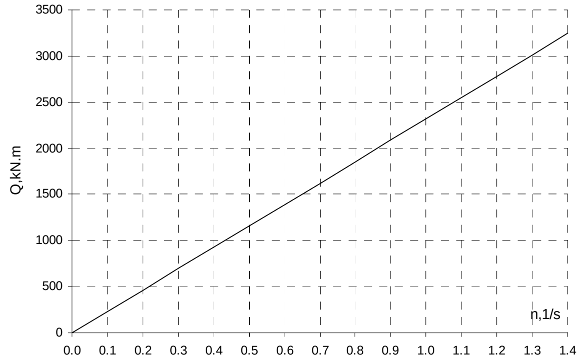


Fig. 2. typical limiting torque curve $Q_{\max}(n)$

Calculation of calm-water resistance

Re	$v_s L_{pp} / \nu$	$4.330 \cdot 10^8$
C_F	$0.075 \cdot (\log \mathrm{Re} - 2)^{-2}$	$1.7 \cdot 10^{-3}$
R_{cw}	$0.5(1+k) C_F \rho S v_s^2$	69.63 kN

Calculation of aerodynamic resistance

R_{air}	$C_{\mathrm{air}} \frac{1}{2} \rho_{\mathrm{a}} A_{\mathrm{F}} v_{\mathrm{w}}^2$	640.15 kN

Calculation of added resistance in waves

10 Added resistance in waves was computed with a potential sea keeping code; here the maximum added resistance over peak wave periods in the range 8.5 to 13.5 s with the significant wave height 9.8 m was used, R_{aw} =1157.6 kN.

Calculation of the required thrust

T	$R_{\mathrm{cw}} + R_{\mathrm{air}} + R_{\mathrm{aw}}$	1867.4 kN

Calculation of the required advance ratio and rotation speed

11 The advance speed of the propeller is calculated as $u_{\mathrm{a}} = v_{\mathrm{s}}(1-w)$ resulting in u_{a} equal to 0.926 m/s. The required advance ratio of the propeller J is found from equation (2), rewritten as $\ln\frac{K_{\mathrm{T}}(J)}{J^2} = \ln\frac{T}{\rho u_{\mathrm{a}}^2 D_{\mathrm{P}}^2}$, where the dependence $\ln\left[K_{\mathrm{T}}(J)/J^2\right]$, Fig. 3, is calculated from the open-water propeller curve, and the right-hand side $\ln\left[T/(\rho u_{\mathrm{a}}^2 D_{\mathrm{P}}^2)\right]$ is equal to 3.084 [–]. From the plot in Fig. 3, the required advance ratio J is found as 0.114 and then the required rotation speed $n = u_{\mathrm{a}}/(JD_{\mathrm{P}})$ as 0.822 1/s.

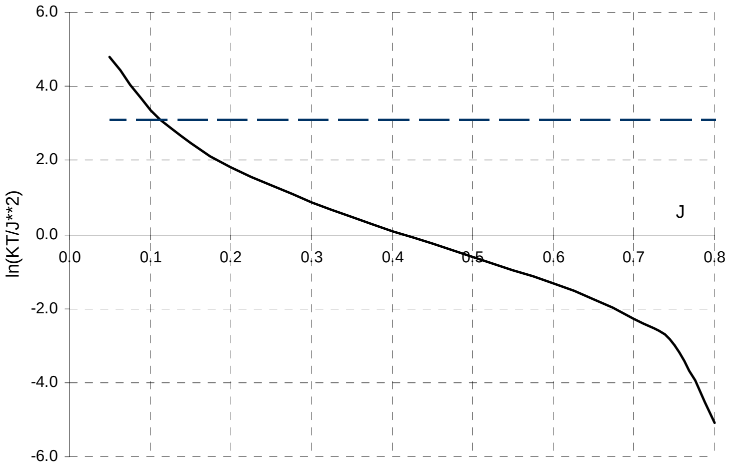


Fig. 3. Dependence $K_{\mathrm{T}}(J)/J^2$

Calculation of the required power

12 For the determined J, K_Q is found from the open-water propeller curve in Fig. 1; then the required delivered power on the propeller is found:

K_Q	Fig. 1	0.0293
P_D	$2\pi\rho n^3 D_{\mathrm{P}}^5 K_{\mathrm{Q}}(J)$	9.74 MW

13 The required propulsion power is less than the delivered propulsion power at design speed of 18.2 MW, compare table 1.

Check of the torque/speed limitation

Q	$P_{\mathrm{D}}/(2\pi n)$	1886.5 kN·m
$Q_{\max}(n)$	Fig. 2	1904.1 kN·m

Thus, the additional criterion $Q < Q_{\max}(n)$ is fulfilled.

14 In summary, the vessel has passed the advance speed assessment.