SNAMES

The Royal Institution of Naval Architects

INSTITUTE OF MARINE Engineering, Science & Technology

SSA SINGAPORE SHIPPING ASSOCIATION

TECHNICAL WEBINAR

Regulating The Safe Navigation of Energy Efficient Ships In Adverse Conditions

11th November 2021

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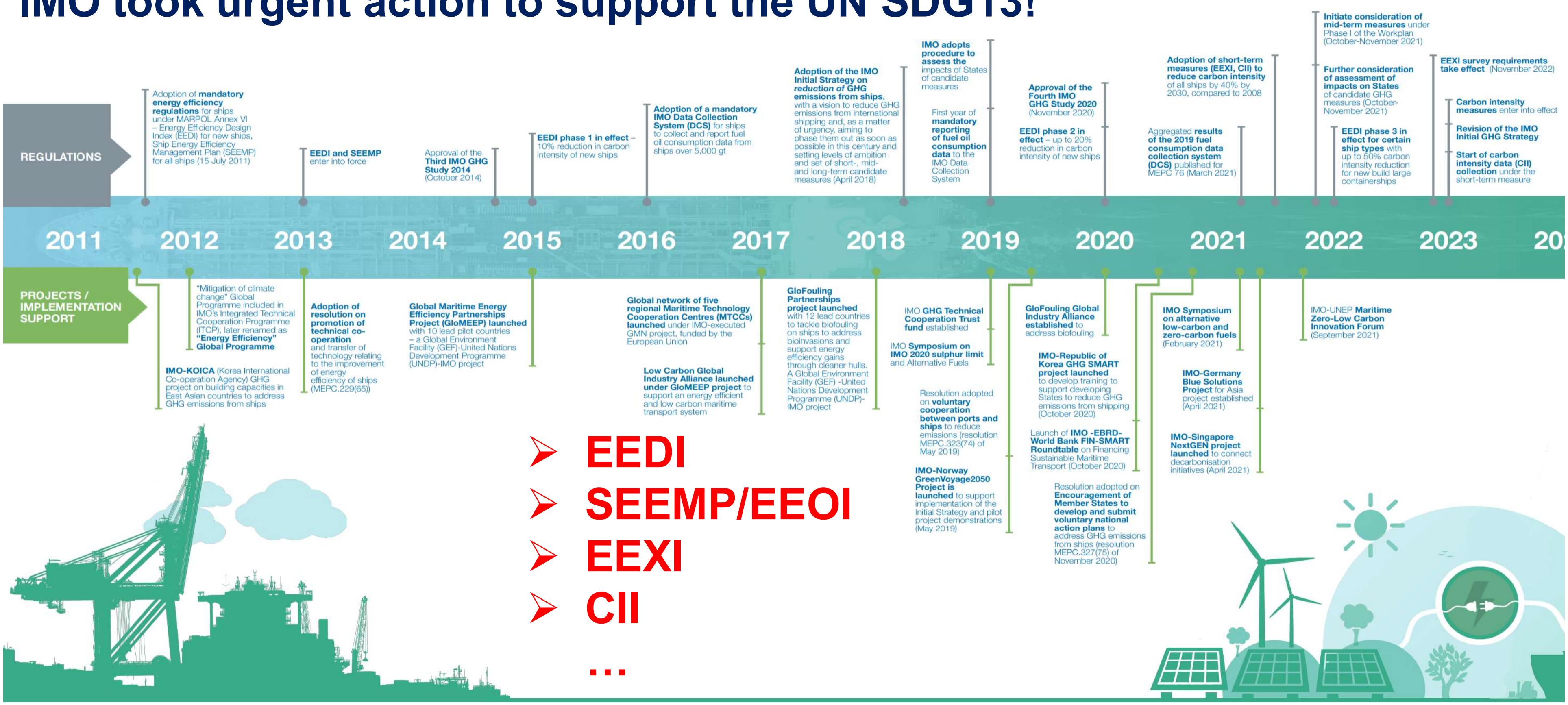
Reminder to Participants: Please record your attendance by keying in your 1) name, 2) company and 3) associated membership (e.g. SNAMES, Joint Branch, SSA or non-member) in the chat window before starting of the webinar. Thank you!

Content

- ***Background***
- ***Regulation Development***
- ***Case Study***
- ***Countermeasures***
- ***Conclusions & Way forward***

Background

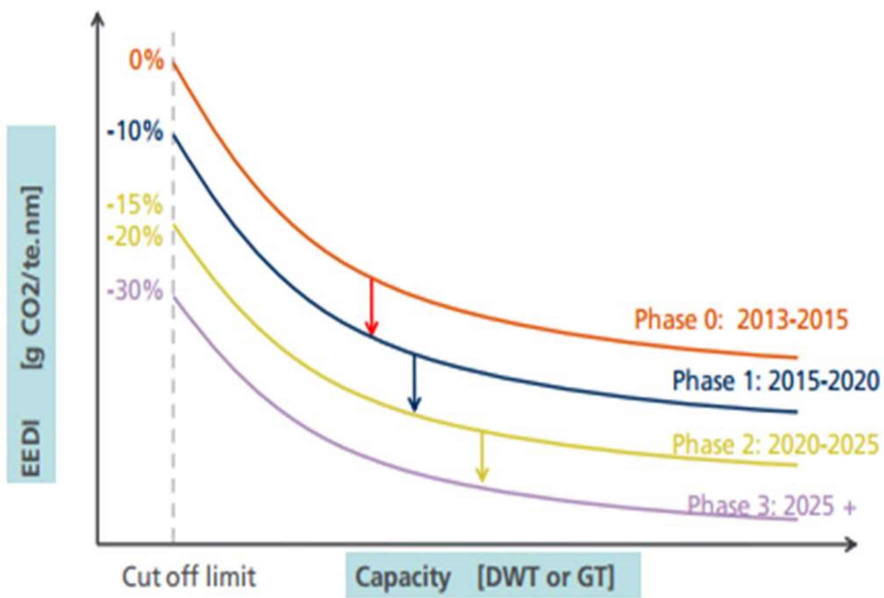
IMO took urgent action to support the UN SDG13!

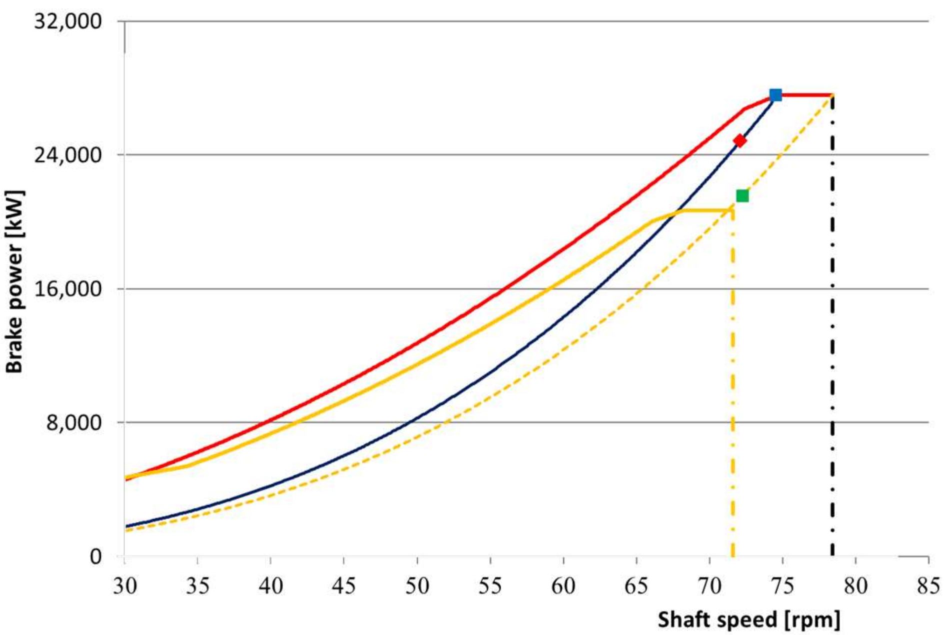


- EEDI
- SEEMP/EEOI
- EEXI
- CII
- …

Why Minimum Propulsive Power Assessment?

$$\underset{(g/ton \cdot nm)}{EEDI} = \frac{P \times SFOC \times C_F}{Capacity \times V_S} \propto \frac{V_S^2 \times SFOC \times C_F}{Capacity}$$



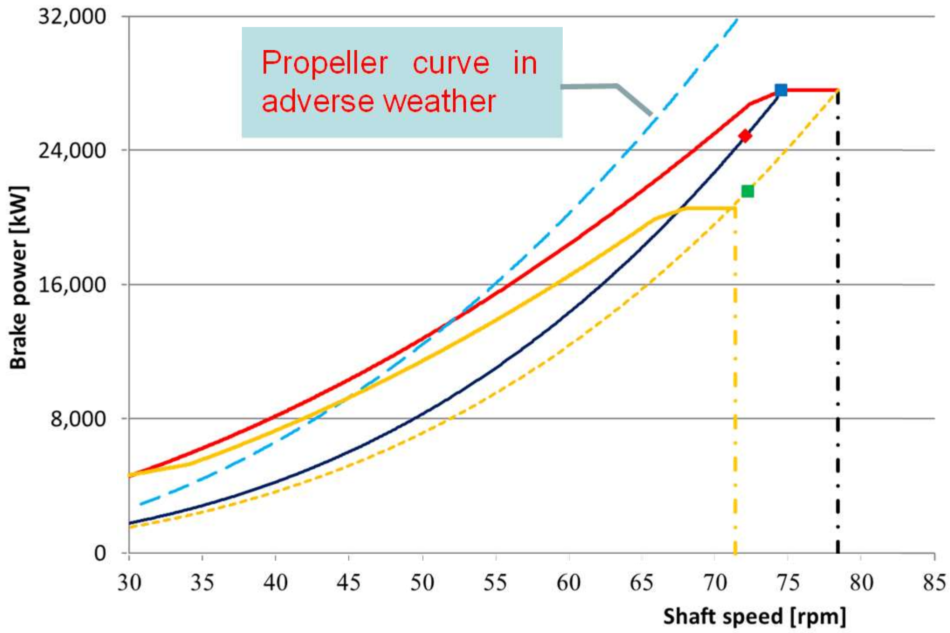


Attained EEDI ≤ Required EEDI

Under-powered ships

Why Minimum Propulsive Power Assessment?

$$\text{EEDI (g/ton·nm)} = \frac{P \times SFOC \times C_F}{Capacity \times V_S} \propto \frac{V_S^2 \times SFOC \times C_F}{Capacity}$$



Under-powered ships are unsafe!

Weather-Vaning; Escape from coastal water; Course-keeping at limited speed

Why Minimum Propulsive Power Assessment?

The 76,741 DWTton Panamax bulk carrier *M/V Pasha was* launched in 2006. It ran aground during the once-in-thirty year storm that struck the Central Coast and Newcastle on June 8, 2007.

Photo: portnews.com.au

Development of IMO Guidelines for MPPA

2010	EE-WG 1	Consideration of safety issues related to the EEDI
2010	MEPC 61/5/32	safety implications of EEDI were considered & Indicates the need to maintain a minimum speed in adv. conditions
2011	MEPC 62/5/19 &INF.21	Draft interim guidelines for *minimum propulsion power to ensure safe manoeuvring in adverse conditions*
2012	MEPC 64/4/13 & INF.7	Proposal of guidelines to determine min propulsion power
2013	MEPC 65	**Resolution MEPC.1/Circ.850/Rev.1** : Interim Guidelines valid for Phase 0 of EEDI (2013-01-01 to 2014-12-31); Revokes the Interim Guidelines MSC-MEPC.2/Circ.11.
2014	MEPC 67	**Resolution MEPC 255(67) :** Amendments to the 2013 Guidelines, Phase 0 and 1 (~2019)
2015	MEPC 68	**Resolution MEPC 262(68) :** Amendments to the 2013 Guidelines, a&b in Level 1 changed
2015	MEPC 69/INF.23	Progress report of SHOPERA & JASNAOE
2016	MEPC 70/5/20 & INF.30	Draft revised guidelines (Scenarios of adverse conditions, ship speed, added resistance …)
2017	MEPC 71/INF.28	Draft revised guidelines
2017	MEPC 71	**Resolution MEPC.1/Circ.850/Rev.2** : Extend validity of 2013 Guidelines to EEDI Phase2 (2020-2024)
2018	MEPC72/5/9 & INF.16	China proposed amendments of the wake fraction and thrust deduction fraction, etc.
2020	MEPC 75/6/3	Finalization of the revised 2013 Interim Guidelines
2021	MEPC 76	**Resolution MEPC.1/Circ.850/Rev.3** : Amendments : definition of adverse weather conditions & a new minimum power assessment method ... It revokes MEPC.1/Circ.850/Rev.2.

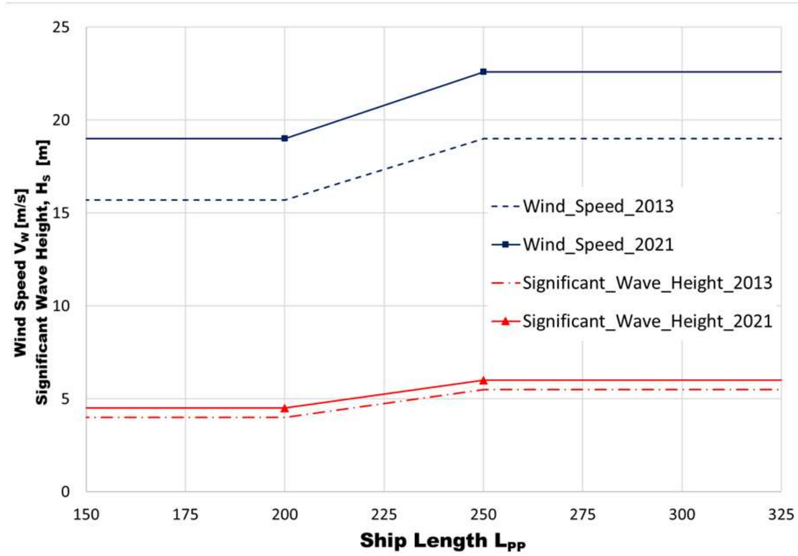
Major Amendments

1. Revised definition of adverse conditions

2. A new "minimum power assessment" method built upon the methodology of "maximum total resistance in the longitudinal ship direction over wind and wave directions from head to 30 degrees off-bow", rather than "course-keeping of the ships in waves and wind from all directions".

3. The navigational speed for assessment is defined to be 2 knots.

4. Revised default conservative estimates : t = 0.1 and w = 0.15



Recommended values for wake fraction w, Ver. 2013

Block coefficient	One propeller	Two propellers
0.5	0.14	0.15
0.6	0.23	0.17
0.7	0.29	0.19
0.8	0.35	0.23

$\eta_{H,\,2013} = 1.16$ vs $\eta_{H,\,2021} = 1.06$

5. Recommended methods for added resistance in waves.

Added Resistance Due to Waves

MEPC.1-Circ.850-Rev.1 (2013) INTERIM GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER

3.12 The added resistance in waves, R_{aw}, defined by the adverse conditions and wave spectrum in paragraph 1 of the interim guidelines, is calculated as:

$$R_{aw} = 2\int_0^{\infty} \frac{R_{aw}(V_s,\omega)}{\zeta_a^2} S_{\zeta\zeta}(\omega)\, d\omega \tag{4}$$

where $R_{aw}(V_s,\omega)/\zeta_a^2$ is the quadratic transfer function of the added resistance, depending on the advance speed V_s in m/s, wave frequency *ω in rad/s*, the wave amplitude, ζ_a *in m* and the wave spectrum, $S_{\zeta\zeta}$ in m^2s. The quadratic transfer function of the added resistance can be obtained from the added resistance test in regular waves at the required ship advance speed V_s as per ITTC procedures 7.5-02 07-02.1 and 7.5-02 07-02.2, or from equivalent method verified by the Administration.

MEPC.1-Circ.850-Rev.3 (2021) GUIDELINES FOR DETERMINING MINIMUM PROPULSION POWER

15 The maximum added resistance due to waves X_d is defined in accordance with either

.1 expression $X_d = 1336(5.3 + U)\left(\frac{B\cdot d}{L_{PP}}\right)^{0.75} \cdot h_s^2$

.2 or spectral method $X_d = 2\int_0^{\infty}\int_0^{2\pi} \frac{X_d(U,\mu',\omega')}{A^2} S_{\varsigma\varsigma}(\omega')D(\mu-\mu')\, d\omega'\, d\mu'$

where $\frac{X_d}{A^2}(N/m^2)$ is the quadratic transfer function of the added resistance in regular waves and A is the wave amplitude;

$S_{\varsigma\varsigma}(\omega')$ is the seaway spectrum specified as JONSWAP spectrum with the peak parameter 3.3;

$D(\mu-\mu')$ is the spreading function of wave energy with respect to mean wave direction specified as $\cos^2$-directional spreading;

…

19 The quadratic transfer functions of added resistance in regular waves $\frac{X_d}{A^2}$ are defined from seakeeping tests or equivalent methods verified by the Administrations or the Recognised Organisations. Alternatively, the semi-empirical method specified in appendix of this document can be used.

Semi-Empirical Method

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Prediction of the Added Resistance in Seaways for Better Ship Design and Operation

Dr. Liu Shukui

School of Mechanical and Aerospace Engineering

Co-Organised by
The Joint Branch of the RINA and IMarEST (Singapore)
The Society of Naval Architects and Marine Engineers Singapore
Singapore Maritime Academy

Semi-Empirical Method

Liu S., Papanikolaou A. and Zaraphonitis G. (2015),"Practical approach to the added resistance of a ship in short waves", Proc. 25th ISOPE, KONA-USA, Vol. 3, pp. 11-18.

Liu S. & Papanikolaou A., (2016), "Prediction of the added resistance of ships in oblique seas", Proc. 26th ISOPE, Rhodes, Greece.

Liu S. and Papanikolaou A. (2016), "Fast approach to the estimation of the added resistance in head waves", Ocean Engineering, Volume: 112, pp. 211-225.

Liu S., Shang B., Papanikolaou A. and Bolbot V. (2016), "Improved formula for estimating the added resistance of ships in engineering applications", Journal of Marine Science and Applications, Vol. 15(4), pp. 442-451.

Liu S. and Papanikolaou A. (2017), "Approximation of the added resistance of ships with small draft or in ballast condition by empirical formula", Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, Vol. 233(1), pp. 27-40.

Liu S. and Papanikolaou A. (2020). "Regression analysis of experimental data for added resistance in waves of arbitrary heading and development of a semi-empirical formula", Ocean Engineering.

Liu S. (2020). Revisiting the influence of a ship's draft on the drift force due to diffraction effect. Ship Technology Research, Vol. 67(3), pp. 175-180.

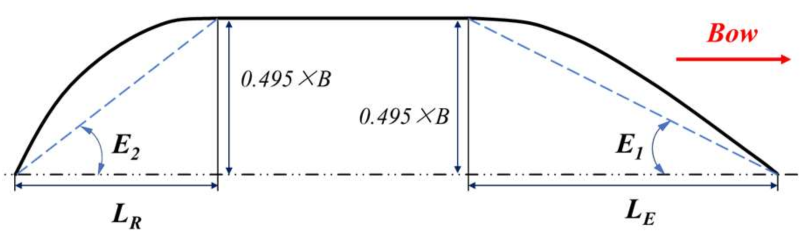
Mourkogiannis D. and Liu S. (2021). Investigation of the influence of the main dimensional ratios of a ship on the added resistance and drift force in short waves, Proc. ISOPE.

Wang J., Bielicki S., Kluwe F., Orihara H., Xin G. Kume K., Oh S., Liu S., Feng P. (2021). Validation study on a New Semi-empirical Method for the Prediction of Added Resistance in Waves of Arbitrary Heading in Analyzing Ship Speed Trial Results. *Ocean Engineering*. https://authors.elsevier.com/c/1duSK6nh6z8GS

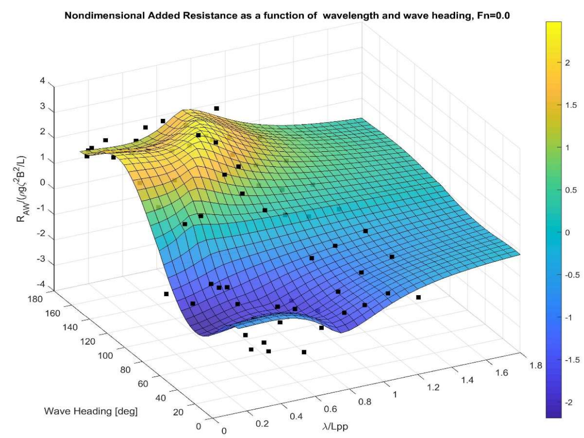
Semi-Empirical Method

- A formula that can be processed by MS EXCEL with simple input.
- The formula is able to track the impact of the variation of main ship particulars and can deal with different speeds and loading conditions.

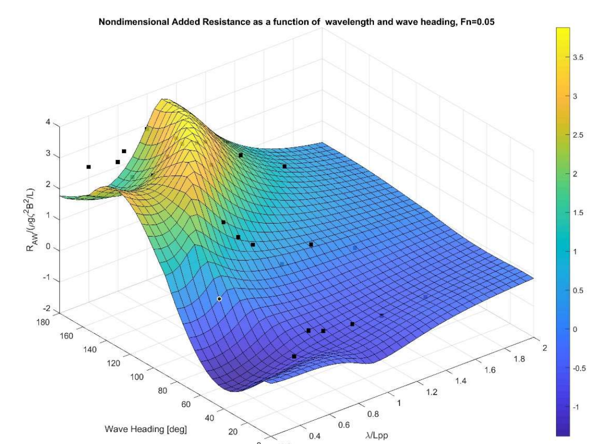
1) 269.00 "L_{PP}"
2) 48.00 "B"
3) 16. "T_{fore}"
4) 16. "T_{aft}"
5) 0.803 "C_B"
6) 0.25 "k_{yy}, radius of gyration of pitch nondimensionalized by L_{PP}"
7) 55.0 "L_E"
8) 80.0 "L_R"



Required input



Added resistance of KVLCC2 ship in regular waves, Fn=0.0



Added resistance of a bulk carrier in regular waves, Fn=0.05

Added Resistance Due to Waves

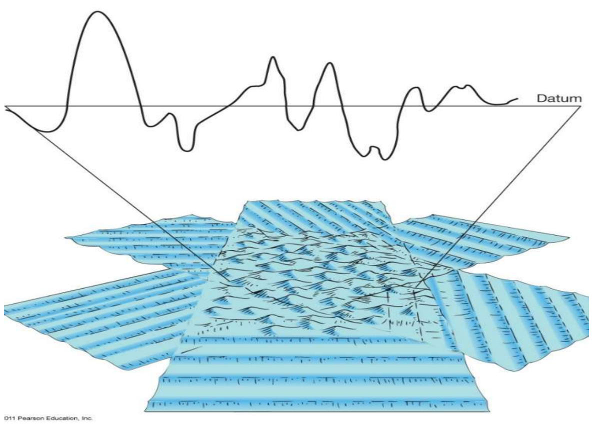
.2 or spectral method

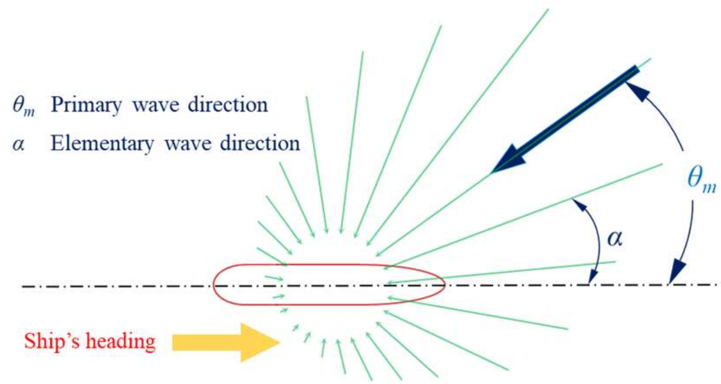
$$X_d = 2\int_0^{\infty}\int_0^{2\pi} \frac{X_d(U,\mu',\omega')}{A^2} S_{\varsigma\varsigma}(\omega') D(\mu-\mu')\, d\omega'\, d\mu'$$

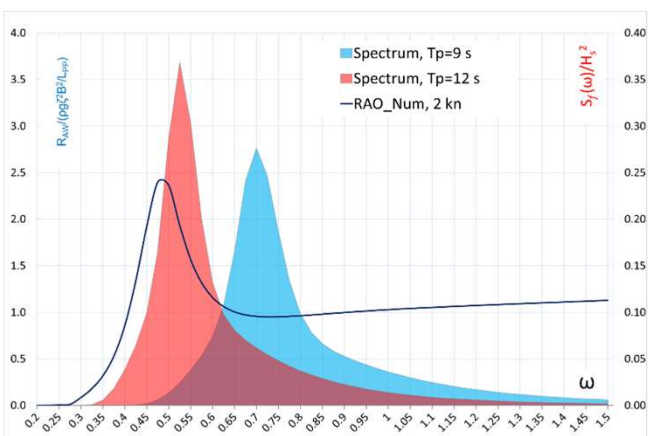
where $\frac{X_d}{A^2}$ (N/m²) is the quadratic transfer function of the added resistance in regular waves and A is the wave amplitude;

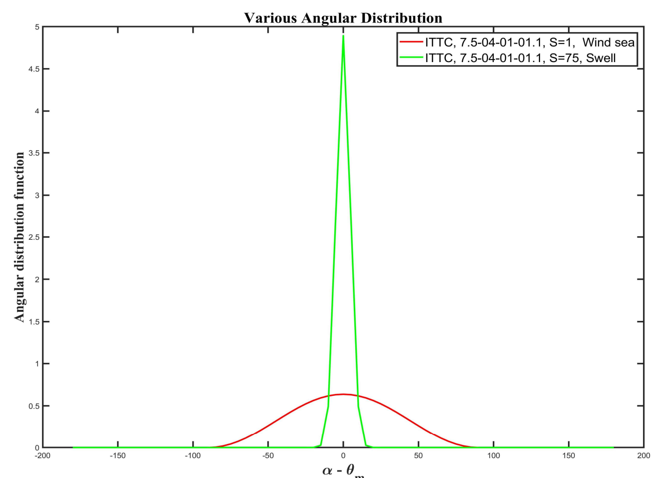
$S_{\varsigma\varsigma}(\omega')$ is the seaway spectrum specified as JONSWAP spectrum with the peak parameter 3.3;

$D(\mu-\mu')$ is the spreading function of wave energy with respect to mean wave direction specified as cos²-directional spreading;









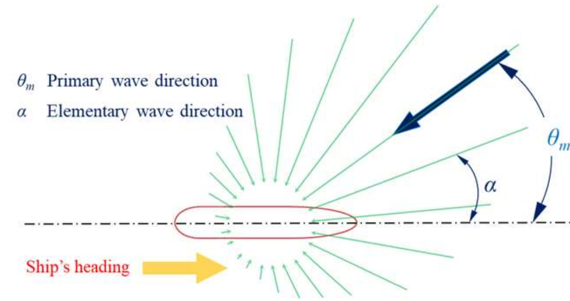
Added Resistance Due to Waves

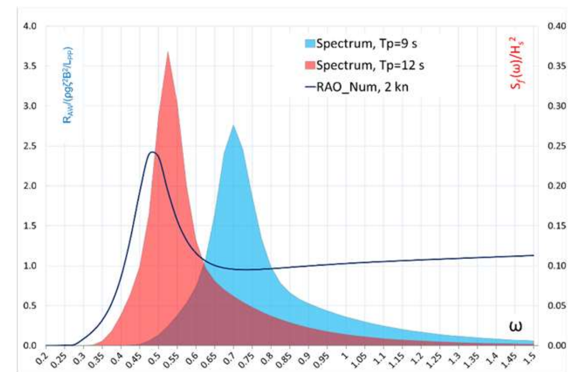
16 The maximum added resistance due to waves X_d is defined as maximum over wave directions from head $\mu = 0$ to 30 degrees off-bow $\mu = 30$. The range of peak wave periods T_P applied in the assessment is from $3.6\sqrt{h_s}$ to the greater one of $5.0\sqrt{h_s}$ or 12.0 seconds …

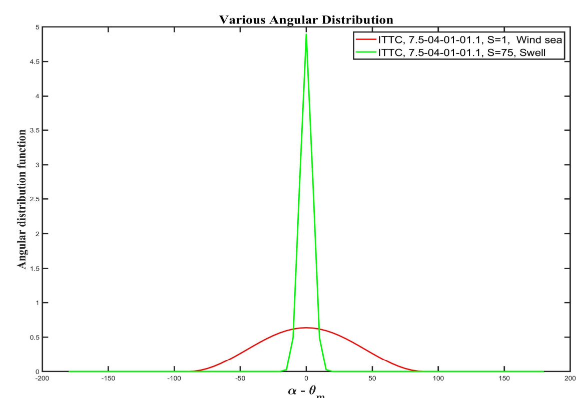
17 The added resistance in short-crested irregular head waves may be regarded as the maximum added resistance over wave directions from head to 30 degrees off-bow, because in short-crested waves, the maximum added resistance over wave directions from head waves to 30 degrees off-bow occurs in head waves.

18 The spreading function $D(\mu - \mu')$ is defined as $\cos^2$-directional spreading. Alternatively, long-crested seaway may be assumed with $D(\mu - \mu') = 1$; in this case, the maximum added resistance due to waves X_d can be determined by multiplying the added resistance in long-crested irregular head waves by the correction factor 1.3, to consider that maximum of the added resistance in long-crested waves does not always correspond to head wave direction.

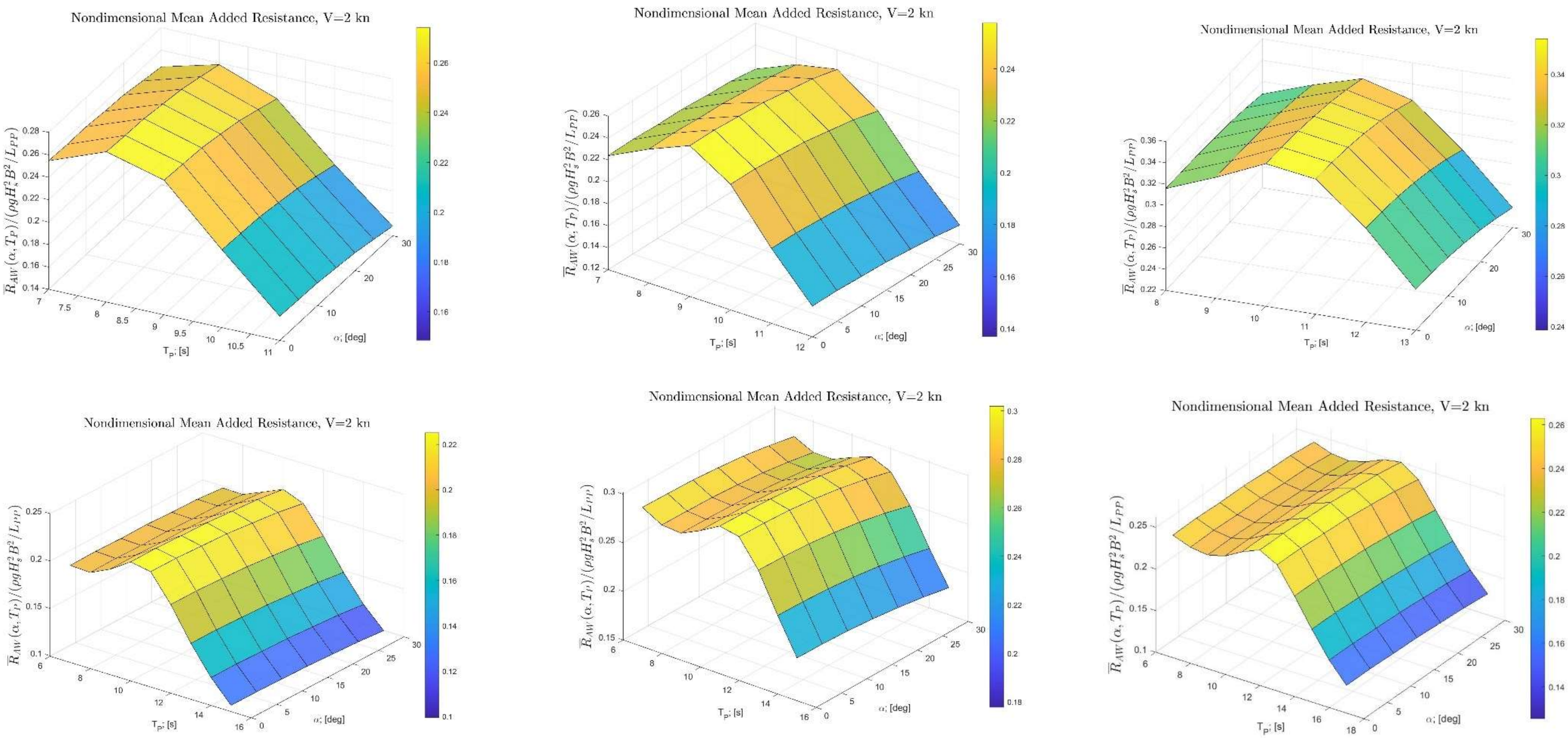
#	METHOD	COMMENTS
1	Maxima of mean value in short-crested head waves to 30° off-bow (Article 16)	RAOs in regular head waves to 120° off-bow (Not possible in towing tank)
2	Maxima of mean value in short-crested head waves (Article 17)	RAO in regular head waves to 90° off-bow (Not possible in towing tank)
3	1.3 × Maximum mean value in long-crested head waves (Article 18)	RAOs in regular head waves (can be done in a wide tank !)







Added Resistance Due to Waves



Mean added resistance of the six subject ships in short-crested bow waves from head μ = 0 to 30 degrees off-bow μ = 30.

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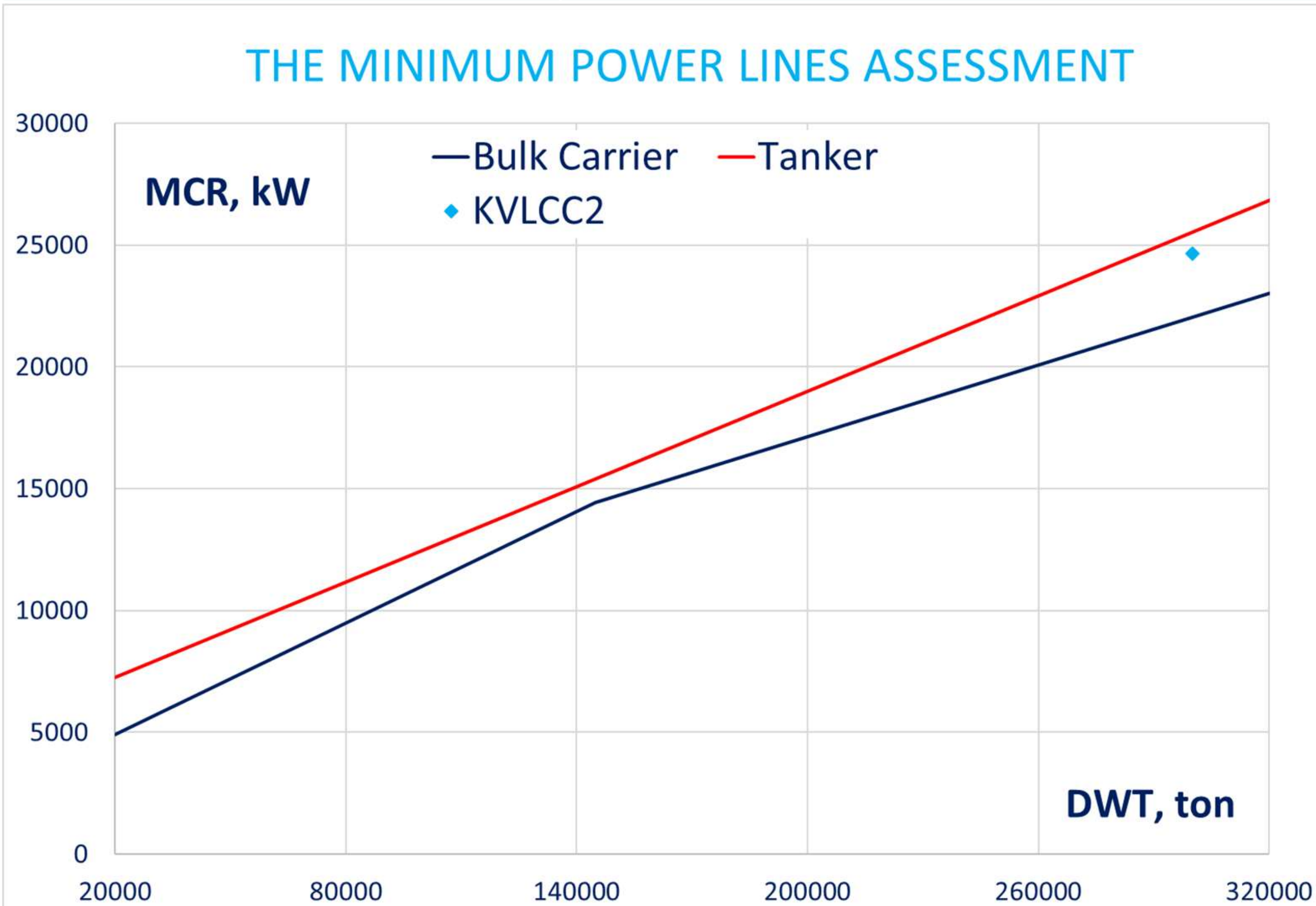
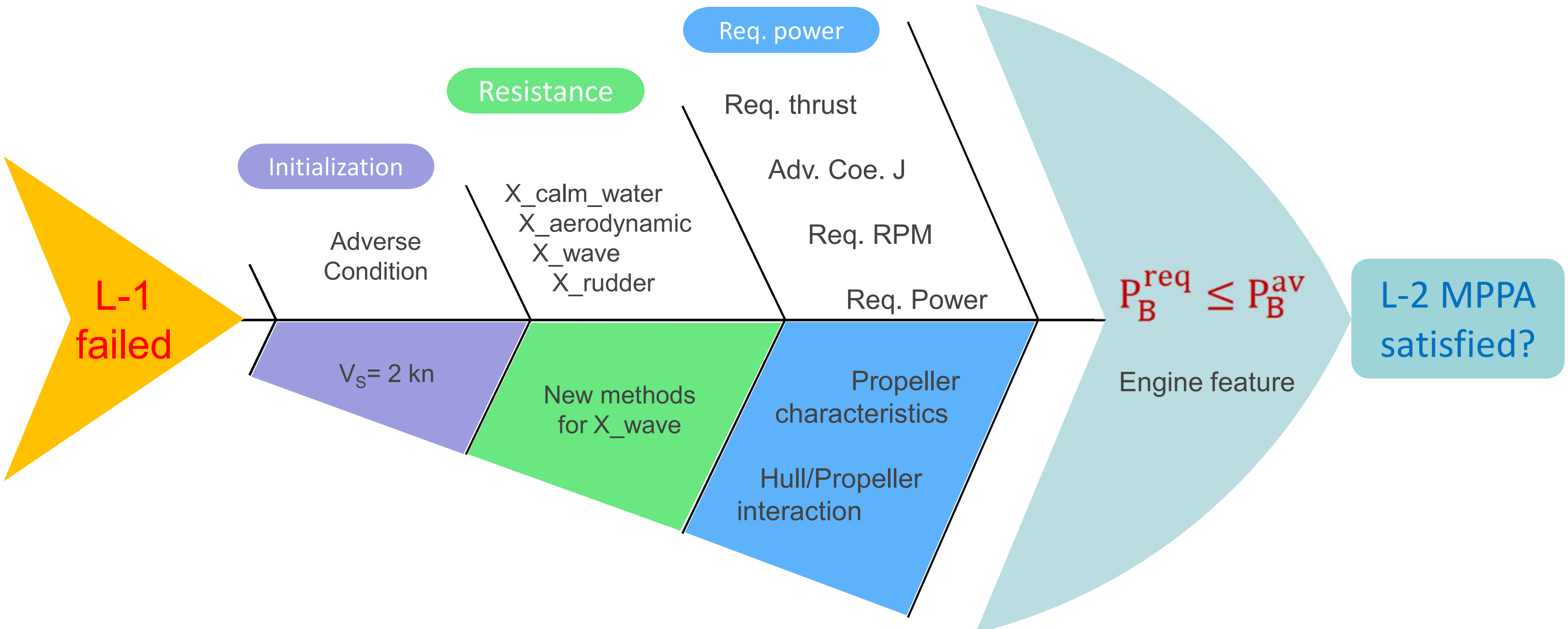
Workflow

KVLCC2	300 kton tanker
Design speed	15 knots
SMCR	24656 kW @ 73.8 RPM w. 5% LRM



Workflow



L-1 failed
Initialization
Adverse Condition
V_S= 2 kn
Resistance
X_calm_water
X_aerodynamic
X_wave
X_rudder
New methods for X_wave
Req. power
Req. thrust
Adv. Coe. J
Req. RPM
Req. Power
Propeller characteristics
Hull/Propeller interaction
$P_B^{req} \leq P_B^{av}$
Engine feature
L-2 MPPA satisfied?

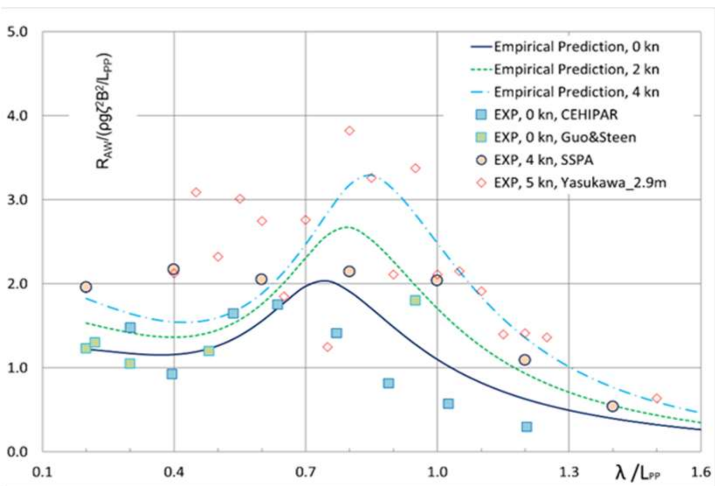
Resistance Components

Calm water resistance at 2.0 knots $X_s = \frac{1}{2}\rho S V_S^2 \cdot (1+k)C_{FS} = 27.8\ kN$

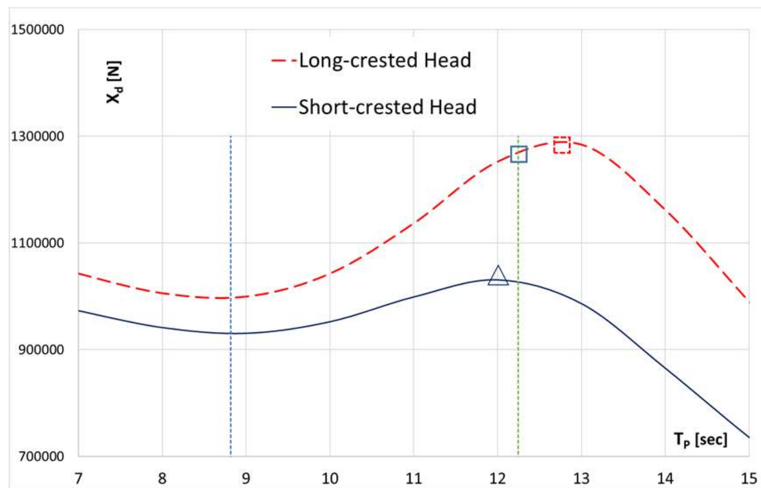
Air resistance $X_w = \frac{1}{2} X'_w \rho_a A_F V_{w,rel}^2 = 442.2\ kN$

Max mean added resistance in irregular waves X_d

Max added rudder resistance X_r

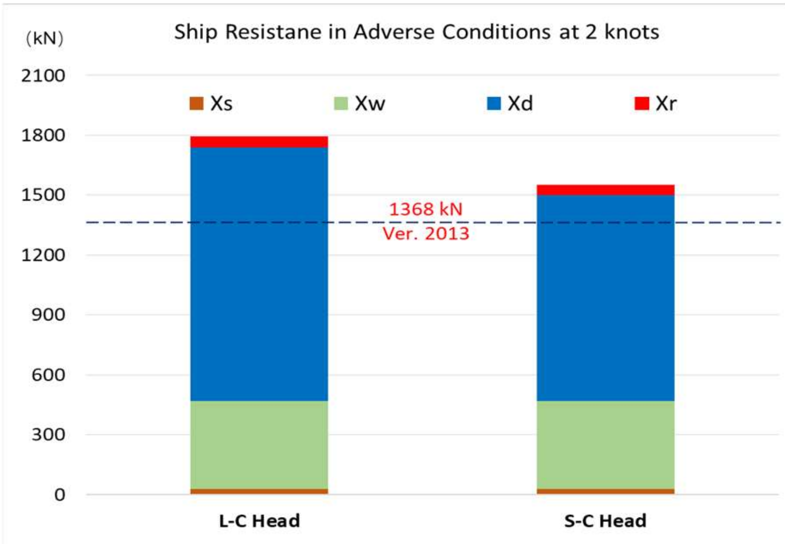


Added resistance of KVLCC2 at lows speeds in regular head waves

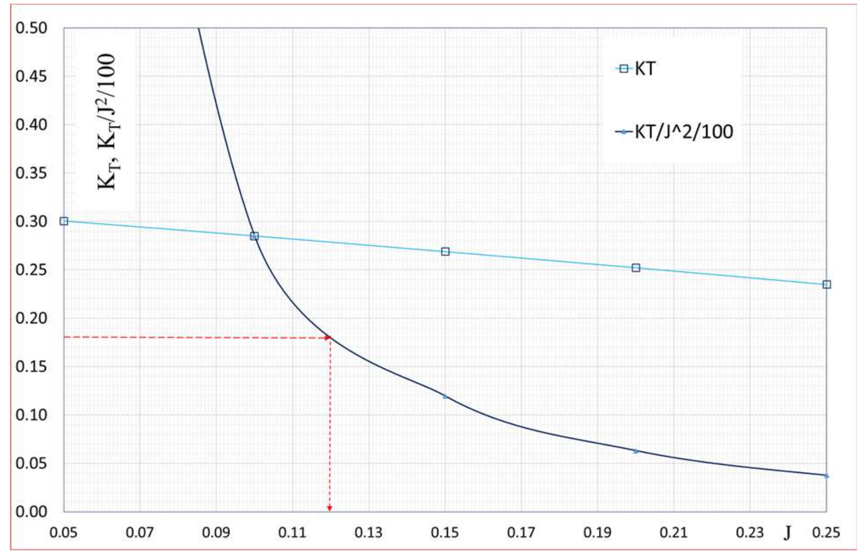


Predicted mean added resistance using recommended methods

Total Resistance & Required Thrust



Components of the total resistance of KVLCC2 at 2 knots in adverse conditions as defined by the IMO Guideline.



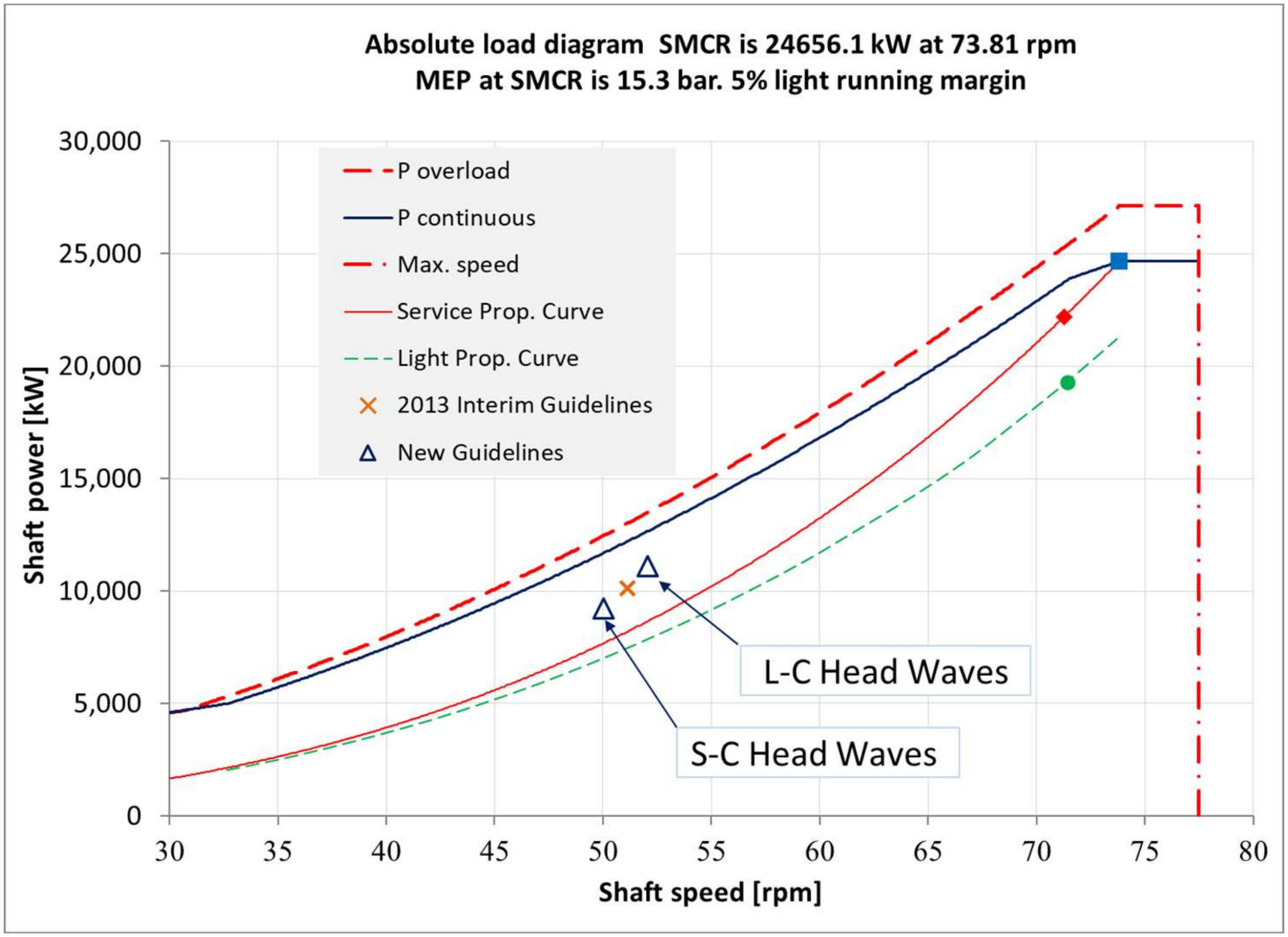
Determination of propulsion point from the propeller open-water characteristics .

	L-C Head	S-C Head	2013
X [kN]	1796	1551	1368
t [-]	0.1	0.1	0.245
T [kN]	1995	1723	1812

Prediction of required thrust following the new and old guidelines

Relaxed requirement on thrust !

Power Assessment



The requirement following Method-2 is slightly higher than the 2013 Interim Guidelines' result and that following Method-3 is slightly lower.

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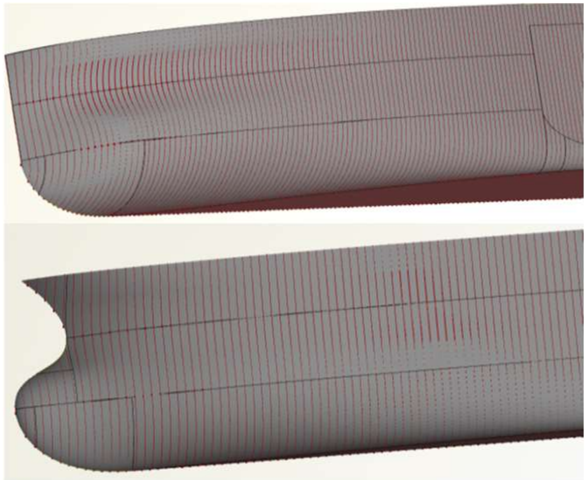
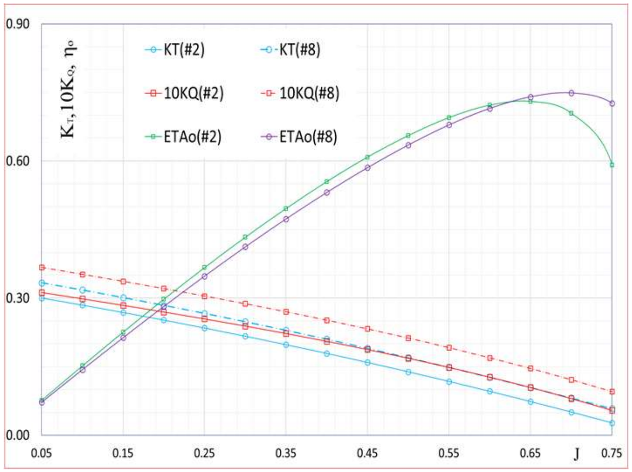
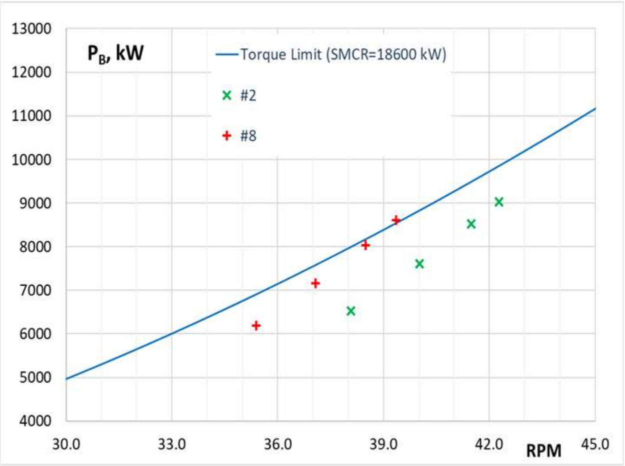
Countermeasures

Holistic optimization, not simple reduction of speed & engine power!

- ❑ Bow form and superstructure optimization for lower added resistance due to wind and waves
- ❑ Stern form optimization for wake fraction and thrust deduction fraction
- ❑ Optimize engine-propeller matching: Larger Light Running Margin in matching between propeller and main engine, considering also fuel efficiency at service speed
- ❑ Modern engines with advanced technology







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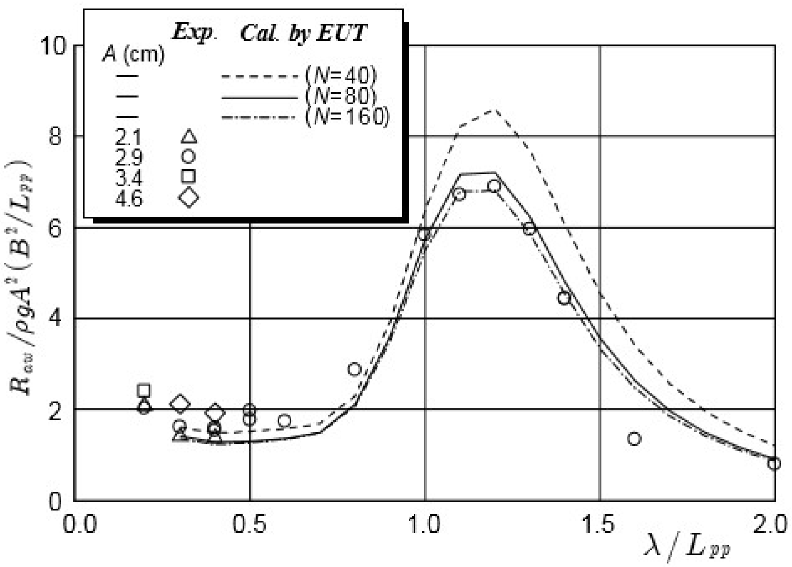
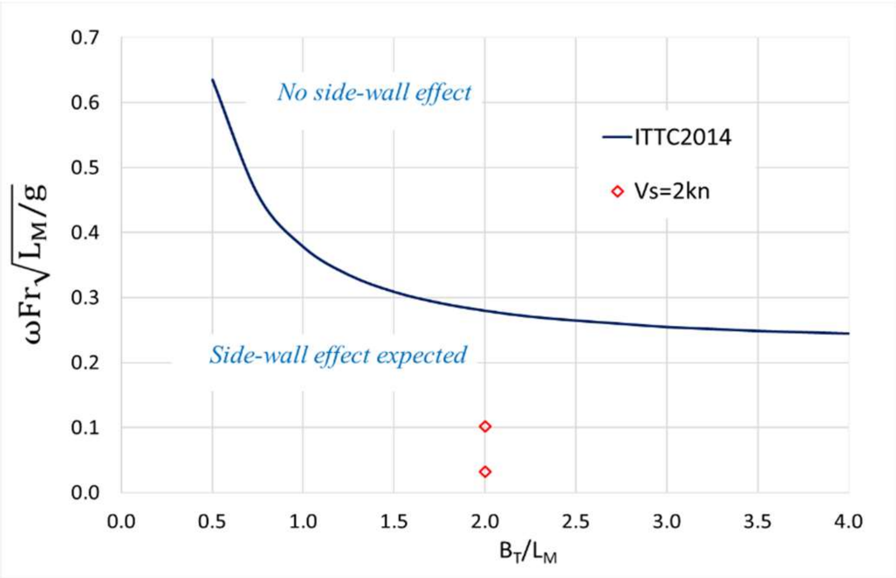
Discussions

- Powering the ships in Phase 3 EEDI implementation while meeting the MPPA requirement will be more challenging.
- More detailed specification on tank testing condition, for instance, wave steepness? (To correspond to adverse conditions.)



Added resistance in waves of SR221C ship model in head waves, full-load condition, Fn=0.15 (Kashiwagi et al. 2004)

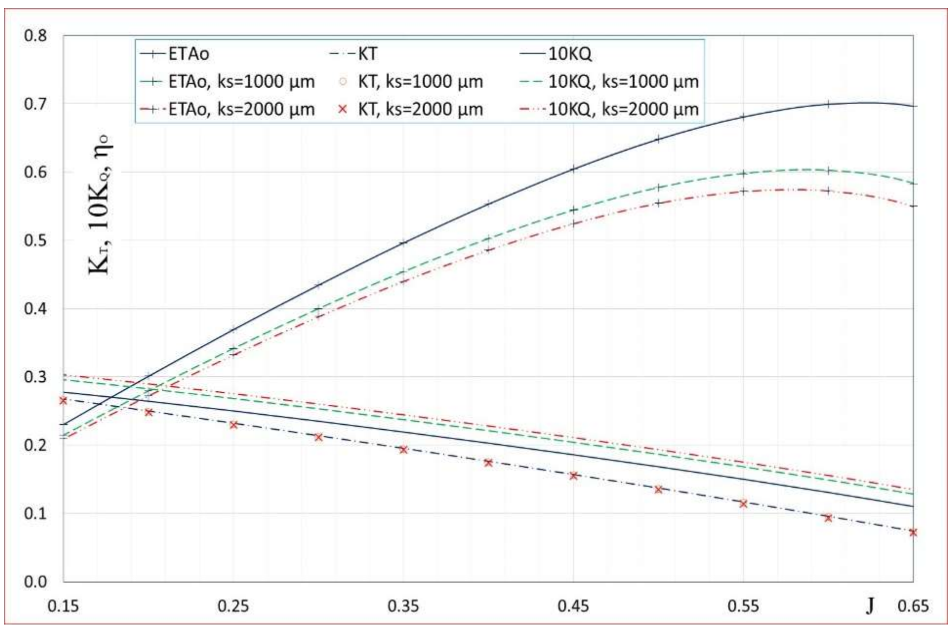


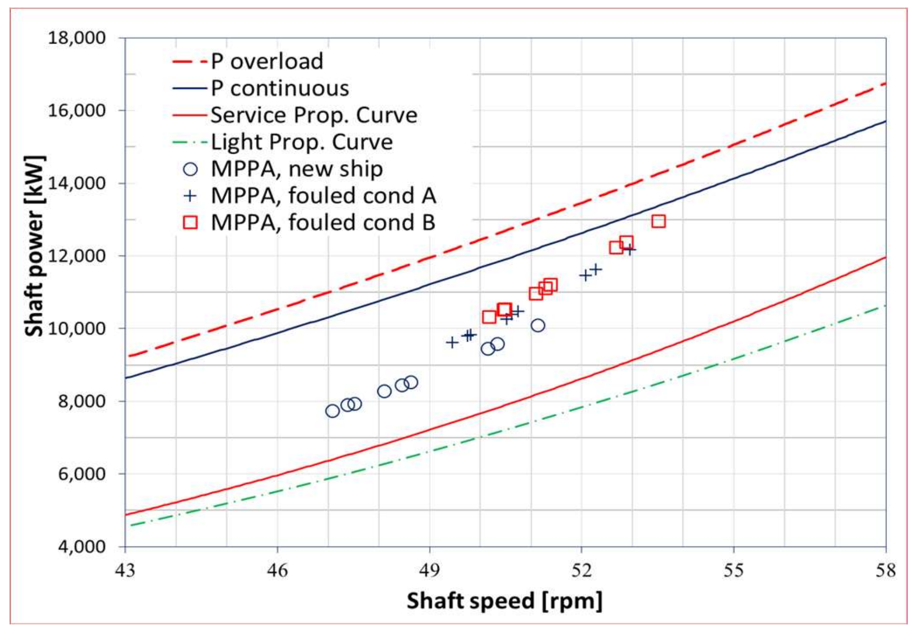
Red points corresponding to λ/L_{PP}=0.2 and 2.0 regular wave of a 5 m long model to be tested at 2 knots for the seakeeping experiments in a 10 m wide tank.

Discussions

- Is advance speed of 2 knots sufficient ?
- Why differentiate the sea conditions according to ship size?
- The influence of aging and fouling on the hull and propellers.
- Ballast condition is more dangerous but not considered.
- Dynamic effect (Acceleration in seaways).

…





Conclusions

1. Review of recent amendments.
2. Critical examination of the new semi-empirical method for added resistance prediction.
3. Case study on KVLCC2.
4. The revised t & w lead to relaxed thrust and power requirement of KVLCC2.
5. Design measures for meeting the requirement.
6. Uncertainties & future development.

REGULATING THE SAFE NAVIGATION OF ENERGY-EFFICIENT SHIPS IN ADVERSE CONDITIONS

Many thanks for your attention!

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