2023

Guidelines on Numerical Calculations for the purpose of deriving the Vref in the framework of the EEXI Regulation

GL-0035-E

KR

Application of “Guidelines on Numerical Calculations for the purpose of deriving the Vref in the framework of the EEXI Regulation”

1. Unless expressly specified otherwise, the requirements in the Guidelines can apply to a numerical calculation report applied for approval by the Provider dated on or after 1 February 2023.

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CHAPTER 1 GENERAL

Section 1 Background

101. Background

1. IMO resolutions MEPC.350(78) and MEPC.351(78) consider Numerical Calculations as an acceptable way to derive the reference speed (Vref) in the EEXI regulation framework. The Guidelines have been developed to provide a methodology for deriving Vref using numerical calculations.

2. Recommendation No.173 developed by the IACS(International Association of Classification Societies) has been comprehensively transposed into the Guidelines, while some requirements have been added and/or adjusted to achieve a clearer interpretation of the wording in some paragraphs at the Society's discretion.

Section 2 Application

201. General

1. Numerical calculations methodology presented in the Guidelines involves three (3) steps, which are detailed in **Ch 2** of the Guidelines.

(1) Step 1: Demonstration of qualification
(2) Step 2: Validation/Calibration
(3) Step 3: Calculation

2. This methodology can be applied to the following scenarios:

(1) In cases where a new speed versus power curve should be derived at the EEDI/EEXI draft in cases where the vessel has not been subjected to modifications; and
(2) In case where the vessel has been subjected to modifications, the methodologies described hereafter can still be used where Step 2 Validation/Calibration in **Ch 2, 202**. is computed with the original hull and Step 3 Calculation in **Ch 2, 203.** is performed on the modified hull

Section 3 Supporting Documentation/Guidelines

301. ITTC publications: Guiding documents for numerical calculations

The following supporting guidelines are to be followed and referred to when performing Numerical Calculation. Whenever possible, these should be followed and applied. Deviations may be accepted as indicated in this document or as approved by the Society.

(1) ITTC 7.5-03-01-02, Rev.02, 2021
(2) ITTC 7.5-03-01-04, Rev.00, 1999 [1)]
(3) ITTC 7.5-03-03-01, Rev.00, 2014

[1)] ITTC 7.5-03-01-04. Rev.00, 1999 (CFD User's Guide) has been deleted by ITTC; however, Resolution MEPC.351(78) keeps its reference to the ITTC publication.

Section 4 Definitions

401. Definitions

1. **Numerical Calculations** are understood as being computer aided calculations in which the Navier-Stokes equations are resolved by means of a Computational Fluid Dynamics (CFD) solvers/software, which requires to implement at least Reynolds-Averaged Navier-Stokes equations as governing equations with the consideration of viscosity and in presence of free-surface.

2. **Target shi**p is a vessel under consideration for EEXI approval

3. **Parent hull** is defined as the original hull of the vessel that will be submitted to CFD calculations. Noting that appendages could be modified without changing the main hull (i.e., parent hull) shape.

4. **Similar ship** is a vessel with the similar[2)] hull form, same number of shafts/propellers, within a threshold of 5% difference in terms of LBP, Cb, displacement at Maximum Summer Load Draft, with similar bow shape (e.g., bulbous bow, straight bow, integrated bulbous bow, and etc) and similar stern hull shape and arrangement with appendages.

5. **Set of comparable ships** are those with the similar2 hull form, with the same number of shafts/propellers and with similar bow shape (e.g., bulbous bow, straight bow, integrated bulbous bow, and etc) and stern shape.

6. **Calibration factor** is defined as the ratio between the sea trial power and/or model tests and the numerical calculation found power. The calibration factor can be found as an average of the power settings evaluated in Sea Trials and/or models test and by numerical calculation. The calibration factor can also be computed and applied at each power setting, if preferred. ⚓

2) Similar can be regarded same ship type at the discretion of the Society. In some cases, e.g. RO-RO Cargo Carrier, RO-RO Passenger Carrier and RO-RO Cargo Carrier (Vehicle) may be considered as having similar hull form, although having different ship type. The same would apply to the cases of change of ship type, where preference would be to refer to the original ship type for the definition of similar.

CHAPTER 2 NUMERICAL CALCULATIONS METHODOLOGY

Section 1 General

As per Resolution MEPC.351(78), numerical calculation can be used as a complement to model tests or as a replacement of the latter. It is nonetheless stated that the methodology and numerical model used need to be validated/calibrated against parent hull sea trials and/or model tests, with the approval of the Society. The methodology to be applied is as follows.

Section 2 Numerical calculations procedure

201. Step 1: Demonstration of qualifications.

1. It should be demonstrated by the Provider their ability to carry out CFD predictions.
2. The Provider may refer to the demonstration process as outlined in the ITTC 7.5-03-01-02, Rev.02, 2021 (referenced in Resolution MPEC.351(78)), or an alternative methodology provided which is approved by the Society.
3. This demonstration should be performed against a reference set of comparable ships. Public domain hull forms and validation tests may be used, such as KCS, KVLCC1, KVLCC2, JBC, DTC, etc.

202. Step 2: Validation/Calibration

1. In case model test or sea trials are available, the numerical models used are to be calibrated against the parent hull.
2. By calibration one understands as the procedure of finding the ratio between the target values (sea trials or model tests) and the achieved values. One understands that it is not possible or not pertinent to fully replicate the model test and/or sea trials. In that case, the results achieved by means of numerical calculations can be calibrated against the model test or sea trials results.
3. The calibration should be conducted after the results from the CFD calculations have been completely post-processed. If the simulations are performed in model scale, the scaling should be performed following the ITTC 78 procedures (or deviations of it, following the principles as outlined in IACS PR38 Rev.3) and the final values are to account for roughness and appendages, where applicable.
4. In case model tests and/or sea trials are not available, or if the CFD provider does not use them for justifiable reasons, the calibration needs to be conducted against a similar ship or a set of comparable ships. The validation can be demonstrated both in model and full scale.
5. It is noted that the paragraph 2.3 of Resolution MEPC.351(78) refers to both words validation and calibration of the numerical models. Further in the same resolution, reference is mainly given to “calibration”. For the purposes of the Guidelines, it is understood that the word validation and calibration are intended to have similar meaning. As further outlined in the Guidelines, The Society has taken the position to apply strict limits to the calibration factor which fall under acceptable thresholds applied by the industry to validate numerical models.

203. Step 3: Calculation

1. The calculation of the new reference speed or speed versus power curve is performed for the target ship.
2. The same numerical calculation procedure as in **Ch 2, 202**. should be used. Additionally, the results are to be corrected to model test or sea trial conditions using a calibration factor obtained from **Ch 2, 202.**
3. Based on the above **Ch 2, 202.** and **203.** the options are summarized in the chart below and detailed in the following sections.

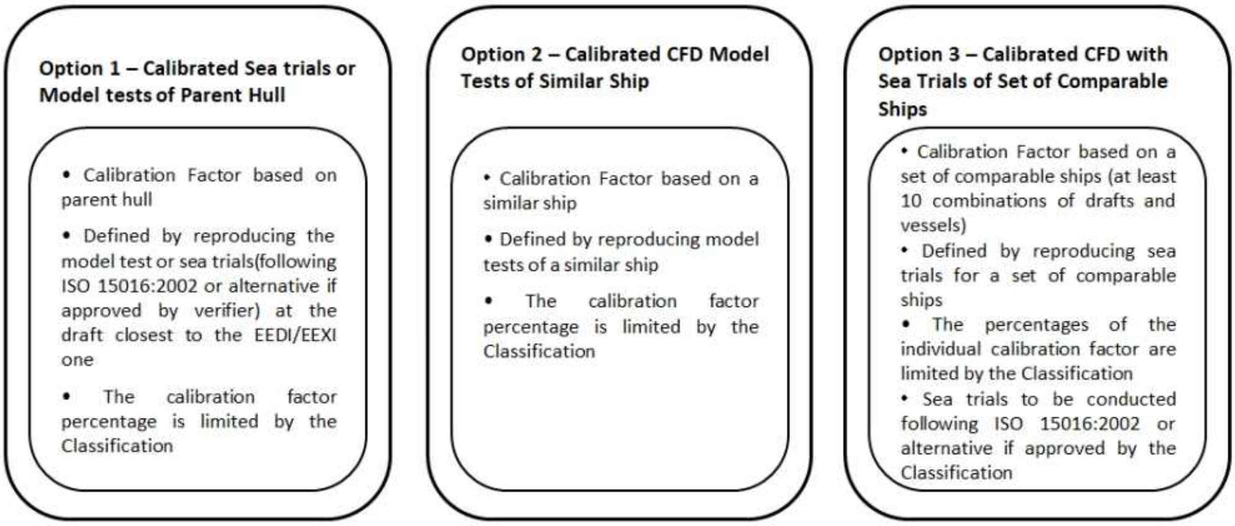

Figure 2.1 3 options for deriving calibration factors and CFD validation

Section 3 Detailed options

301. Option 1 – Calibrated CFD with sea trials or model tests of parent hull

1. In this case, the baseline for comparison would be the availability of previous sea trials or model tests for the vessel in a draft different than the one required for the EEXI or in a different configuration. In such scenario, firstly a simulation would be performed at full or model scale and at the same draft and configuration as the one in the sea trials or model tests. The draft closest to the EEXI draft should be selected.

2. Sea trial results that have been scaled from ballast draft to laden draft based on model test results can be used. Sea trials are to be performed following ISO15016:2002, or the equivalent if satisfactory and acceptable to the Society.

3. The CFD results are then post-processed to account for details not included directly in the simulations (e.g., appendages, hull roughness, windage) to arrive at the CFD predicted power.

4. In case of model scale simulations, the results need to be extrapolated to full scale following ITTC 78 (or deviations of it, following the principles as outlined in IACS PR38 Rev. 03). As far as possible the conditions as in the model test are to be followed (Ca, ITTC procedure, how appendages have been accounted for, etc).

5. A calibration factor would then be computed by comparing the CFD predicted power to the Sea Trials or model tests.

6. Then, a new CFD simulation would be performed at the EEXI draft and possibly new configuration (e.g., bulbous bow retrofit, new propeller, etc), the same post-processing would be applied, and the correction factor computed previously can be applied to the CFD predicted power obtained for the EEXI draft to achieve the EEXI Draft Sea Trials Conditions Speed versus Power Curve.

7. If the achieved calibration factor lies between 0.95 and 1.05, this can be considered as acceptable to the Society without further technical justification. However, if the calibration is lower than 0.95 or higher than 1.05, a technical explanation should be provided, documented and approved by the Society and the limit of individual calibration factors lie between 0.90 and 1.10.

8. This general principle is to follow the same reasoning that is currently applied to correct model tests to the sea trial conditions, using as reference the calibration factor which is a ratio between the sea trial and model test results at the sea trial draft.

9. The detailed process for Option 1 can be depicted as follows:

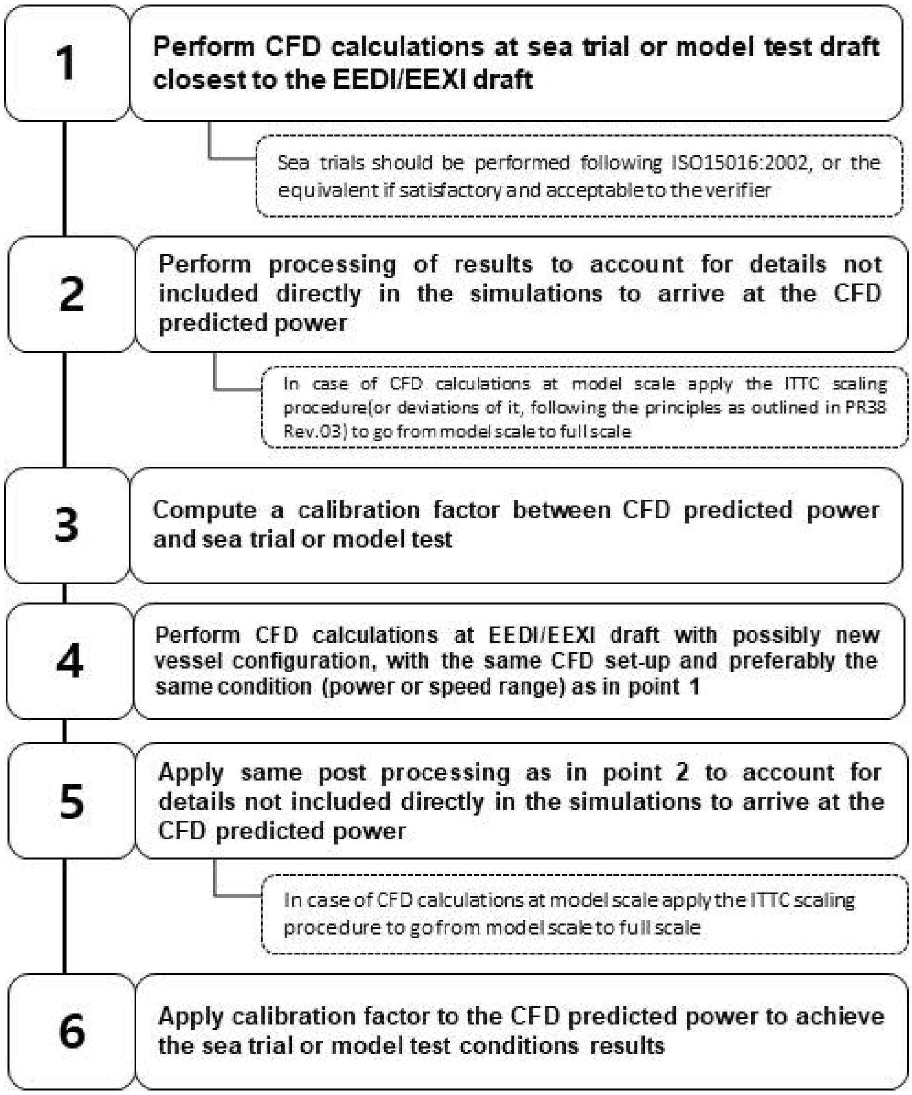

Figure 2.2 Work process for Option 1

302. Option 2 – Calibrated CFD with model test of similar ship

1. In this case, the procedure is similar to that for Option 1 with the exception that the calibration is conducted based on model tests performed following the applicable ITTC procedures.

2. If the achieved calibration factor lies between 0.95 and 1.05, this can be considered as acceptable to the Society without further technical justification. However, if the calibration is lower than 0.95 or higher than 1.05, a technical explanation should be provided, documented and approved by the Society and the limits of individual calibration factors lie between 0.90 and 1.10.

3. The detailed process for Option 2 can be depicted as follows:

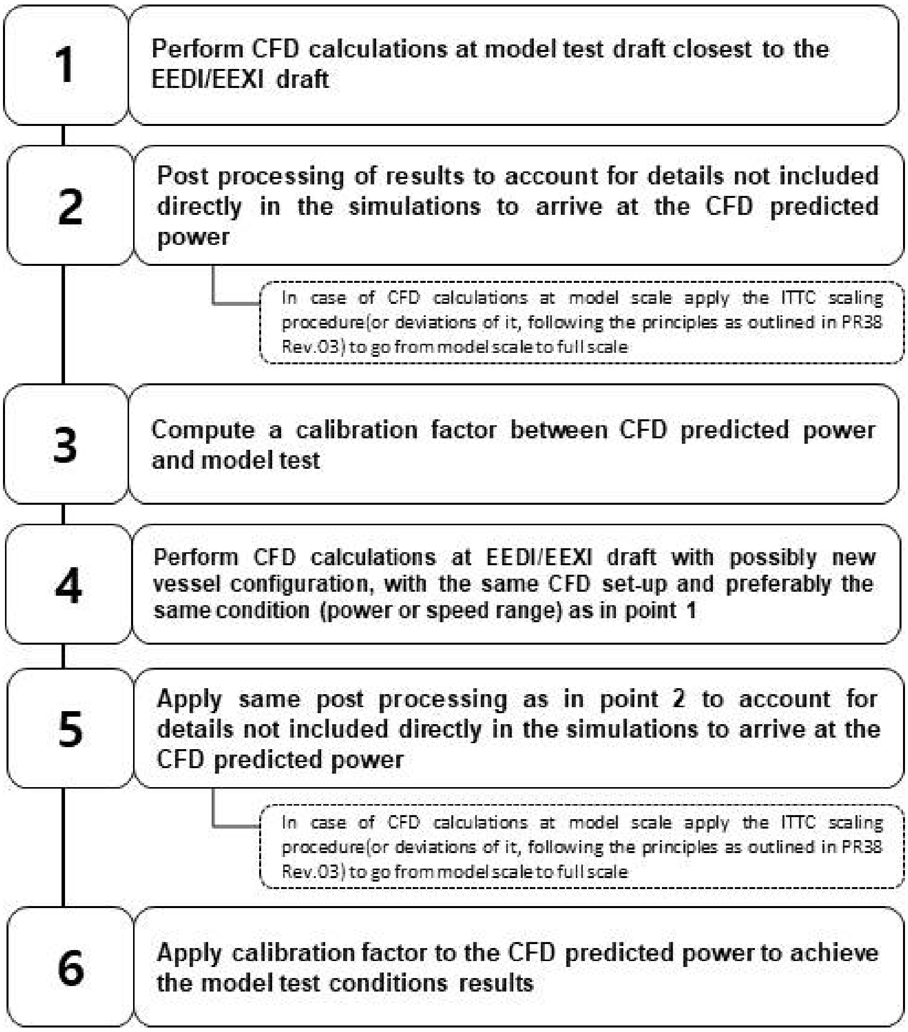

Figure 2.3 Work process for Option 2

303. Option 3 - Calibrated CFD with sea trials of a set of comparable ships

1. In this case, the procedure is the same as that for Option 1 with the exception that the calibration is conducted based on sea trials of a set of comparable ships.

2. Sea trial results that have been scaled from ballast draft to laden draft based on model test results CANNOT be used.

3. Sea trials are to be performed as per ISO15016:2002, or the equivalent if satisfactory and acceptable to the Society. Sea trials in ballast and laden condition should be included in the assessment.

4. As a minimum, at least 10 combinations of vessels and drafts need to be included when deriving a unique calibration factor. Such unique calibration factor should be derived from the individual calibration factors calculated for every ship in the database calculated and the methodology should be approved by the Society.

5. The individual calibration factors are limited to be between 0.90 and 1.10. If the individual calibration factor lies between 0.95 and 1.05, this can be considered as acceptable to the Society without further technical justification. However, if the calibration lies between 0.90 and 1.1, a technical explanation should be provided, documented, and approved by the Society.

6. The LBP, displacement and Cb (both at EEXI/EEDI draft) of the target vessel should not lie below

or above the values from the dataset of vessels used to derive the calibration factor.

7. The calibration factor should only be interpolated and not extrapolated, for the referenced particular. In addition, the calibration factor should be achieved on the basis of a regression curve or surface and should not be a simple average of the 10 combinations of vessels and drafts. In either case it is to be verified the accuracy and representativeness of the dataset used to derive the calibration factor, i.e., that these are evenly spread across the range of LBP, displacement and Cb. It is also to be verified that at least 2 vessels of the database are between 0.85 and 1.15 LBP of the target ship.

8. With Option 3, the Provider is exempted from demonstrating qualifications as per **Ch 6, 202.** All the simulations contained in the database are to be done following at best the requirements outlined in **Ch 3** of the Guidelines. The Society may require access to the details of the calculations included in the database to derive the calibration factor.

9. The detailed process for Option 3 can be depicted as follows:

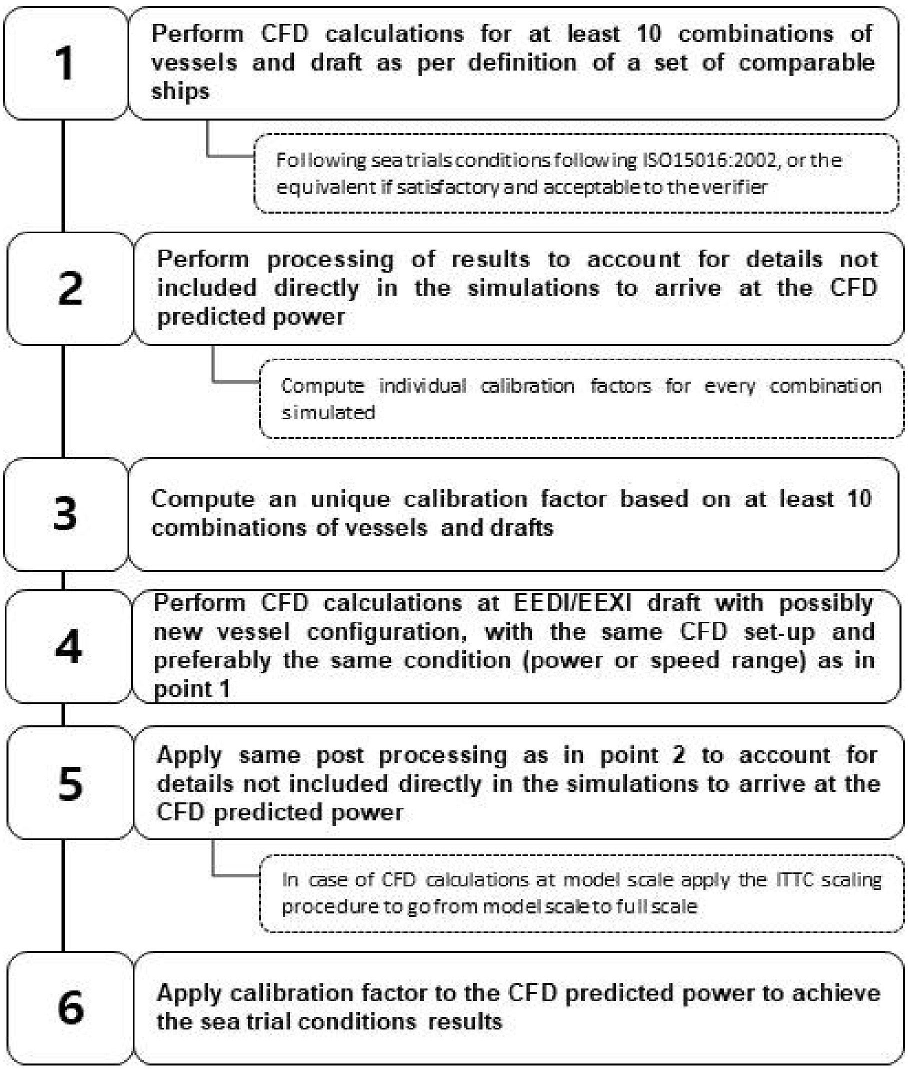

Figure 2.4 Work process for Option 3

CHAPTER 3 NUMERICAL CALCULATIONS MODELLING

Section 1 General

101. General

1. Technical aspects to be applied to the simulations are detailed in this chapter.

2. If additional matters other than those specified in this chapter are deemed necessary to be included in the CFD report, it may be requested additional materials from the Provider at the discretion of the Society.

Section 2 Scale

201. Scale in simulations

1. Technically, simulations can be performed both at model and full scale. The following preference should be given to each of the options listed in **Ch 2, Sec 3.**

2. For Option 1, preference is given to model-scale simulations if calibrating against model tests and full-scale simulations may be accepted if approved by the Society.

3. For the other options, both scales may be used. The validation/calibration and calculation need to be conducted at the same scale.

Section 3 Numerical modelling requirements

301. Key numerical modelling requirements

Information on the required numerical modelling is provided in Table 3.1.

Table 3.1. Details on the required numerical modelling level

Item	Requirement
Geometry	Fully appended, if not possible then appendages not accounted for should be corrected using other methods (empirical methods, etc). If not feasible, then this should be included in the calibration/correlation factor.
Definition of domain	·Inlet: 5LBP ~ 10LBP, ·Outlet: 3LBP ~ 5LBP ·Side: 2LBP ~ 4LBP In case alternative ranges is used. this may be accepted upon demonstrated validation against a set of comparable ships
Governing equation	At least RANS(Reynolds Average Navier Stokes) equations.
Degrees of freedom	Model should at least be free in heave and pitch.
Y+ values	ITTC 7.5-03-02-03 to be followed.
Propeller modelling	As a minimum requirement, actuator Disk. Note that for Energy Efficiency Technologies, other requirements are set in Ch 4 and Ch 5.
EET modelling	Full model is required.
Free-surface	VOF(Volume Of Fluid) or Level set is recommended but alternative ones may be accepted upon demonstrated validation against a set of comparable ships.
Numerical scheme	At least 2nd order upwind is required but alternative ones may be accepted upon demonstrated validation against a set of comparable ships.
Turbulence model	Industry is commonly using k-w SST or RSM as standard model for marine applications. This should be the preferred model but alternative ones (at least two equations models) may be accepted upon demonstrated validation against a set of comparable ships.
Time discretization	Simulations should be resolved in the time domain or in a quasi-steady approach.
Post-processing	It needs to be demonstrated that enough time steps are accounted for in the averaging of final results so to smooth potential oscillations in the results.
Roughness	Roughness should not be taken into account directly in the numerical simu-lations, but in post-processing of the results following the ITTC procedure. If roughness is included in the numerical simulations, detailed validation should be demonstrated by the company providing the numerical calculation. This validation should be demonstrated for a set of comparable ships.
Turbulence intensity	It should not exceed 10%. In case a higher value is used, this should be documented and the reason for such to be justified and validated against a set of comparable ships.
Time step	ITTC 7.5-03-02-03 is to be followed.

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CHAPTER 4 ENERGY EFFICIENCY TECHNOLOGY

Section 1 General

101. Applicability

Energy Efficiency Technologies (EET) as per MEPC.1/Circ.896 may also be included in the simulations. To that extent, it is understood that the following technologies are not covered by the Guidelines:

1. Air Lubrication (EET-B)
2. Hull painting and coatings (EET-A)

In the future, the Guidelines may be revisited to include for the above.

For the others, it is suggested that the methodology to follow, as much as possible, the same principles as described previously in the Guidelines.

Section 2 Requirements

201. Objective

The procedure suggested to be applied relies on finding the improvements in power due to the addition of the EET and applying these as a correction factor on previously already obtained speed power curves (from sea trials, model test or other CFD calculations).

202. Procedure

The power improvements of EET are to be calculated by comparing the results from two simulations, with and without EET, as follows:

1. Perform two simulations, with and without presence of EET.
2. Compute the gains delivered by the EET by comparing the power difference from the simulation with EET with the one without EET.
3. Apply the gains on top of the final Speed versus Power Curve as derived following options in Ch 2, or as previously available from existing sea trials and/or model tests.

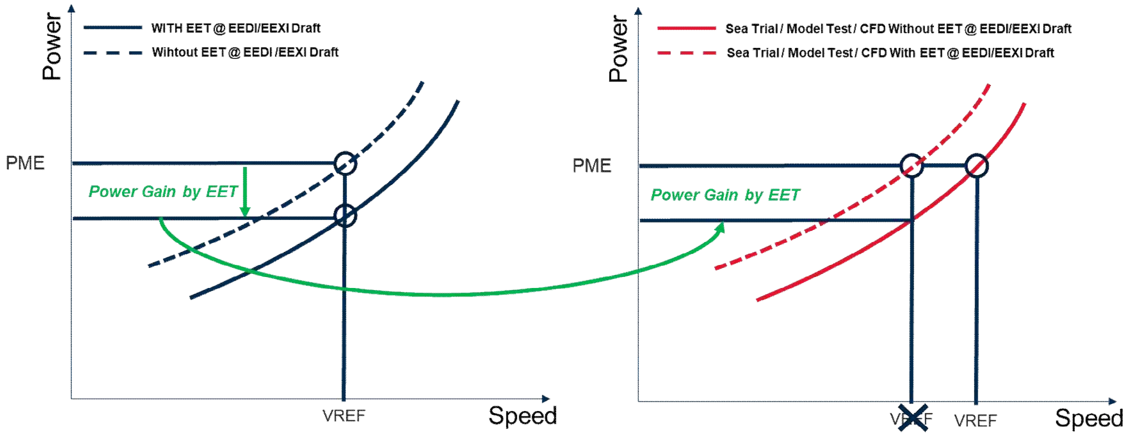

Figure 4.1 Application of correction factor derived from w/ and w/o ESD simulations

203. Items to be considered

The following aspects are required to be verified and/or improved in the simulations when considering energy saving devices before or after the propeller:

1. That the same definition of numerical calculation is applied as in **Ch 1, 401.**

2. Free-surface: the free-surface may not be modelled, if considered acceptable to the Society. It should be demonstrated by evidence that removing the free-surface does not affect the results. Such evidence should include previous validation cases for a set of comparable ships performed by the CFD provider.

3. Hull Geometry: Basically, simulations should be performed in a full modeling condition, but with the consent of the Society, only a section of the hull may be modeled. However, the Provider should verify that there is no difference between the CFD results of removing some sections of the hull and the results of full modeled hull and submit the evidence (e.g., flow pattern into the EET, distribution of ambient pressure, velocity, and etc.).

(1) Only a section of the hull may be modelled. In such case, the boundary conditions are to be set in a way that these represent the flow pattern induced by the part of the hull not represented in the simulation. It should be demonstrated by evidence that removing part of the hull does not affect the results. Such evidence may include previous validation cases performed by the CFD provider against a set of comparable ships.

(2) In case it is demonstrated by sufficient evidence that the same results, in terms of comparative gains, are obtained for a similar ship, then the hull form for a similar ship may be used as a replacement.

4. That the qualifications as per **Ch 6, 202.** are demonstrated, in this case for cases where an Energy Efficiency Technology was considered.

5. That the simulations are performed with the propeller fully modelled, i.e., that its actual surfaces are present in the simulation and are not simplified by means of an actuator disk or another numerical artifice. Lower order models, such as BEM, may be accepted provided that such methodology validation is duly demonstrated.

6. That the simulated propeller RPM without EET should be compared to that of model test or sea trials in the range of the expected advanced coefficient. The differences are expected to be within the thresholds that If the achieved calibration factor lies between 0.98 and 1.02, this can be considered as acceptable to the Society without further technical justification. However, if the calibration factor is lower than 0.98 or higher than 1.02, a technical explanation should provided, documented, and approved by the Society and the limits of individual calibration factors lie between 0.978 and 1.022.

7. In absence of the geometry of the propeller for the target hull, a replacement propeller may be re-built based on the data at disposal. The target should be to achieve a geometry as close as possible to the actual propeller. The provider is expected to demonstrate accuracy of the propeller geometry used by the following means:

(1) If the Kt 10Kq curves of the target propeller are available, the report should show that the replacement propeller provides values no more than 3% different from the target values in the relevant propeller operating range[3] (comparison on the basis Kt, 10Kq and ηO);
(2) If the Kt 10Kq curves are not available, the provider may use as reference an equivalent curve (e.g., Wageningen Series) obtained based on the data at disposal. The report should show that the replacement propeller provides values no more than 3% different from the equivalent ones in the relevant propeller operating range[3] (comparison on the basis Kt, 10Kq and ηO);
(3) The final geometry has the same features (diameter, number of blades, hub diameter, rotating direction) as those that are available to the provider. A table should be provided comparing the features of the replacement and target propeller as per table below:

Item	Replace propeller	Target propeller
Diameter		
Number of blades		
Rotating direction		
Expanded Area Ratio		
Hub diameter		
Chord Length		
Max.thickness		
Pitch Ratio at 0.7R		

Herein, values of the expanded area ratio, max.thickness, and pitch ratio at 0.7R for a replacement propeller should be no more than ±3% compared to those of a target propeller. if these values are out of tolerance, a technical explanation should be provided, documented, and approved by the Society.

8. That the mesh used in numerical model has its convergence demonstrated with the inclusion of the propeller or the alternative model as per point **5.** ⚓

CHAPTER 5 OPEN WATER SIMULATIONS

Section 1 General

101. Applicability

As per Resolution MEPC.351(78), numerical simulations can be used with a view to complementing or replacing the use of model tests for propeller open water calculations. In such a way, this section pertains to discussing the level of requirement to be demonstrated when Numerical Calculations are used for these purposes and the following points are observed:

Section 2 Requirements

201. Requirements to be demonstrated

1. That the same definition of numerical calculation is applied as in **Ch 1, 401.**

2. Fluid domain and boundary conditions are to be set in a way that these do not influence the results obtained. This should be documented in the report to be issued by the provider.

3. Definitions and requirements in **Ch 3** are followed with the following deviations being accepted:

As a minimum requirement, propeller should be modelled using BEM models and Actuator Disk/Force models are not accepted.

4. In replacement to the qualifications as set in **Ch 6 202.**, the report may include a validation report for the proposed methodology on an equivalently similar propeller (i.e. Wageningen B series). The differences between the numerical and expected results should be within 3% in the relevant propeller operating range[3] (comparison on the basis Kt, 10Kq and ηO).

Item	Replace propeller	Target propeller
Diameter		
Number of blades		
Rotating direction		
Expanded Area Ratio		
Hub diameter		
Chord Length		
Max.thickness		
Pitch Ratio at 0.7R		

⚓

[3] By relevant operating range, it is meant the advance coefficient in which the propeller is expected to operate when installed on the vessel and for the EEXI condition of relevance for the analysis. The validation should cover the range of advance coefficients close to the relevant operating points

CHAPTER 6 VERIFICATION

Section 1 General

101. Objective

In this section, the detailed level of requirements that may be included in a Numerical Analysis report to be used as supporting documentation for the development of the EEXI Technical File. For reference, an example of template report is provided in Appendix 1.

Section 2 Reporting Requirements

The report to be submitted to the Society should include the followings.

201. Introduction & Objectives

This section may introduce the work being performed and state the objectives of the simulations. It should be detailed if the simulations are to be performed by calibrations against model test or sea trials of parent hull or reference ships.

202. Qualifications

1. Reference is made to the ITTC 7.5-03-01-02, Rev.02 Quality Assurance in Ship CFD Applications, **Section 5**. The Providers that wish to demonstrate their ability to carry out CFD predictions may refer to the demonstration process as outlined in the reference guidelines. This should be taken as part of the Quality Assurance procedures to be demonstrated by the company carrying out the CFD analysis.

2. This demonstration may include the ship types under consideration, referring to the definition of "set of comparable ships" as per **Ch 1, 401.** or the ship type that is approved by the Society in advance. It remains at the discretion of the Society to assess if the documentation provided is sufficient to ensure the ability of the company to deliver the numerical calculations.

3. Exemption Condition: If Company obtains a calibration factor in accordance with **Ch 2, 303.** as purpose of validation/calibration, the demonstration of qualifications on CFD analysis ability can be exempted.

203. Description of Supporting Documentation

A section should be included in report referencing the supporting documentation used by the company delivering the numerical analysis. As example, the following could be included:

1. Model test report
2. Sea trial report
3. Hull drawings
4. General arrangement
5. Propeller drawings

This should be included in the appendices, if possible and considered necessary by the Society.

204. Vessel Description

A section detailing the particulars of the vessel under consideration should be included in the report. It should account for at least the following:

1. Ship name
2. IMO number and/or Hull number
3. Vessel type
4. Design draft
5. Lightweight and displacement
6. EEXI draft
7. Main engine power/ SMCR and NCR
8. Length between perpendiculars, LBP
9. Beam molded, B
10. Depth molded, D
11. Propeller data:
    (1) Propeller diameter
    (2) Number of blades
    (3) Rotating direction
    (4) Expanded area ratio
    (5) Main dimensions of the hub
    (6) Chord length, Maximum thickness, Pitch ratio at 0.7 R
    (7) Details of ESD(incl. working mechanism), if fitted

205. CFD Software

1. A section containing a description of the CFD software used and the version of the same.

2. However, if Company used an in-house CFD codes, the detailed descriptions on the software and its verification with reference to **Ch 1, 301.**(ITTC 7.5-03-01-04, Rev.00 and ITTC 7.5-03-01-02, Rev.02) or an alternative methodology provided which is approved by the Society is required.

3. This can be part of the Qualifications step as detailed in **Ch 2, 201.**

206. CFD model geometry and mesh

1. A section detailing the geometry model should be included in the report. Any simplifications and omissions should be documented and its impacts on the results to be clearly identified together with remediation actions (if necessary).

2. A table comparing the hydrostatic values and coefficients between the model used in the numerical calculation and those from the model tests or the actual hull as built. The following parameters are to be compared:

Item	CFD model	Actual model
LOA		
LBP		
Breadth(mld.)		
Depth		
Displacement(Including rudder, appendages) at different drafts under consideration in the study		
Wetted surface area(Including rudder, appendages) at different drafts under consideration in the study		
LCB in % of LBP at different drafts under consideration in the study		
VCB from baseline at different drafts under consideration in the study		

3. The Provider should include the comparison pictures between 3D CFD model and actual ship in the report as a front, side, rear, and bird view, and if they are insufficient, the Society may request additional data (e.g. construction, lines plan, and etc).

4. A convergence study should be provided justifying the use of the mesh refinement chosen by the supplier. This can be replaced by a convergence study performed on a different vessel if approved by the Society. Such convergence curve should contain at least 3 discrete mesh sizes.

In addition, the report should include the following information:

(1) Grid sizes and description of the mesh main sizes (boundary layer, cell sizes, etc). These are to be provided for the different refinement zones of the domain and at every direction (x,y,z), if they differ;

(2) Different views of the mesh covering different aspects:

(A) Boundary layer mesh for different parts of the hull if they differ

(B) Close up views of the mesh around key parts of the hull: bow, aft, transom and appendages

207. CFD Set-up

A section containing the details of the CFD set-up used in the calculations. The following should be included:

1. CFD software and version being used
2. CFD equations being solved
3. Simulation type, steady vs unsteady
4. Turbulence model being used and justification for its choice
5. Numerical solution schemes used: for example, second-order upwind and iteration stop criteria
6. Fluid domain dimensions
7. Boundary conditions applied on all the surfaces of the fluid domain
8. Description of the coordinates system and model origin
9. Degrees of freedom used in the model
10. Description on the propeller modelling: full propeller, RANS-BEM, actuator disk, etc.
11. Convergence criteria used to assess if the calculations have converged
12. Description of the initial conditions used

208. Validation Assessment

1. A validation assessment procedure should be performed by the provider.

2. This is to demonstrate that the values obtained are within reasonable and expected values. The goal is not to strictly validate the absolute values contained in the results but rather to validate that the final values and flow pattern obtained agree with physical reality.

3. This should be performed with a qualitative assessment of the results and by demonstration using as supporting documentation quantitative reference values of the results obtained.

4. This can be done by using a subset of the results (graphically and numerically) and justifying how they can be considered “as-expected”.

209. Post-processing and Result

The report should contain an explanation on the post-processing procedure (if averaged, last value, etc.) used. Also, the description of the methodology by which the final self-propulsion point was found (if propeller open water CFD simulations were used, in which case the details of these are also required).

In addition, the results obtained for all the conditions under which the hull under question was assessed: drafts and speeds. The following should be included in the report:

1. One figure showing an example of one of the simulations showing the residuals. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc.;
2. One figure showing an example of a convergence plot of the total resistance, viscous resistance, pressure resistance, propeller thrust. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc.;
   The following views of the flow are required with colour code as a minimum:
   (1) Global view of the wave pattern with wave height
   (2) Zoom view of the wave pattern at the bow and stern regions
   (3) Views of the y+ values for the hull and appendages
   (4) Views of the pressure coefficient for the hull and appendages
   (5) In case propeller is fully modelled or in case an EET is considered, cross section views of flow past the propeller and EET device (normalized velocity and pressure at different cross sections)
3. Summary of values obtained from simulations
   (1) Ship resistance (total, viscous and pressure resistances)
   (2) Thrust deduction factor (1-t)
   (3) Wake deduction factor (1-w)
   (4) Propeller Thrust
   (5) Propeller Torque
   (6) Propeller efficiency
   (7) Rotation Rate
   (8) Delivered Power ⚓

APPENDIX 1 Example of Template Report

1. INTRODUCTION & OBJECTIVE

This report contains the description of the CFD modelling used to derive the EEDI/EEXI reference speed (Vref) for the **VESSEL (NAME)**. The procedure used in this report follows the Society's Guidelines and the most latest ITTC guidelines on the topic of Numerical Modelling. Deviations of these have been properly documented in this report and justification is provided.
The final Reference Speed (Vref) is computed for the EEDI/EEXI draft as per Resolution MEPC.351(78) and the Society's Guidelines (or IACS Recommendation No. 173) following the calibration performed against the available model tests and/or sea trials. The following sections detail the methodology, parameters, post-processing and final results obtained.

2. QUALIFICATIONS

Following ITTC 7.5-03-01-02, Rev.02, evidence on the ability of the consultants delivering this report is provided hereafter.

(1) General qualifications: **COMPANY (NAME)** has been involved in multiple R&D, JIP and JDPs projects covering the topics of ship resistance and propulsive performance for the past XX years. Examples of projects are listed below:

Project no.	Year	Description
1	2013	...
2	2014	...
3	2015	...
4	2020	...
5	2021	...
...	...	...
...	...	...

COMPANY (NAME) has participated in the following benchmarking/validation exercises in which is has obtained the accuracy by employing its standard modelling procedures:

Project no.	Year	Ship type	Description	Scale
1	2015	...	...	model(or full)
2	2016	...	...	model(or full)
3	2017	...	...	model(or full)
4	2019	...	...	model(or full)
5	2020	...	...	model(or full)
...	...	...	...	...
...	...	...	...	...

(2) Case specific qualifications: COMPANY NAME has carried out a number of projects in which ship performance was evaluated by means of Numerical Calculations for ships falling within the category of "set of comparable ships" as per the Society's Guidelines (or IACS Recommendation No. 173).

Project no.	Year	Ship type	Scale
1	2015	...	model(or full)
2	2016	...	model(or full)
3	2017	...	model(or full)
4	2019	...	model(or full)
5	2020	...	model(or full)
...	...	...	...
...	...	...	...

3. SUPPORTING DOCUMENTATION

The following list of supporting documentation was used in connection to these calculations and are provided in the Annex of this report.

Document no.	Document Name	Description
1	Model test report	
2	Sea trial report	
3	Hull lines	
4	General arrangement drawing	
5	Propeller drawing	
...	...	...

4. CFD SOFTWARE DESCRIPTION

(1) A section containing a description of the CFD software used and the version of the same.
(2) However, if Company used an in-house CFD codes, the detailed descriptions on the software and its verification with reference to **Ch 1, 301.** (ITTC 7.5-03-01-04, Rev.00 and ITTC 7.5-03-01-02, Rev.02) or an alternative methodology provided which is approved by the Society is required.
(3) This can be part of the Qualifications step as detailed in **Ch 2, 201.**

5. Vessel Description

A section detailing the particulars of the vessel under consideration should be included in the report. It should account for at least the following.

(1) Vessel

Vessel Name	
IMO Number	
Vessel Type	
Main Engine Type	
SMCR × RPM	
DWT	
LWT	
Design Draft	
EEXI/EEDI draft	
LBP	
Beam molded(B)	
Depth(D)	

(2) Propeller

Diameter	
Number of Blades	
Rotating Direction	
Expanded Area Ratio	
Hub Diameter	
Chord Length	
Max.thickness	
Pitch Ratio at 0.7R	

6. CFD MODEL GEOMETRY

In here the model used in the CFD calculations is presented. It is expected that a comparison between the actual hull as built is compared to the model used in the calculations. This can be done by comparing the hydrostatics between the hull as built and the one used in the CFD calculations. This should be done for the hull and appendages included in the modelling.
In case geometry simplifications have been implement or parts of the vessel have not been accounted for in the CFD model, this must be noted and detailed in this section. Example for different views to be provided are presented below.

Figure 1. Example of different views of a geometry used in CFD analysis

The fluid domain size is also to be detailed here and different views describing the main dimensions should be provided.

7. NUMERICAL MODEL SET-UP DESCRIPTION

In this section, the numerical model should be detailed. This should account for the following information:

(1) CFD equations being solved
(2) Simulation type, steady vs. unsteady
(3) Turbulence model being used and justification for its choice
(4) Numerical solution schemes used: for example, second-order upwind and iteration stop criteria
(5) Boundary conditions applied on all the surfaces of the fluid domain
(6) Description of the coordinates system and model origin
(7) Degrees of freedom used in the model
(8) Description on the propeller modelling: full propeller, actuator disk, etc.
(9) Description of the initial conditions used

An image should be provided to detail the boundary conditions used in the CFD calculation.
The meshing strategy should be detailed. General description of the size of the cell size, type of grids being utilized, boundary layer refinement, etc., should be provided. Different views of the different refinement zones are also to be provided.
The post-processing methodology is also to be detailed here: how open water propeller data is used, if more than two simulations are performed (resistance and self-propulsion), etc. The reasoning used to achieve the self-propulsion point should be detailed.

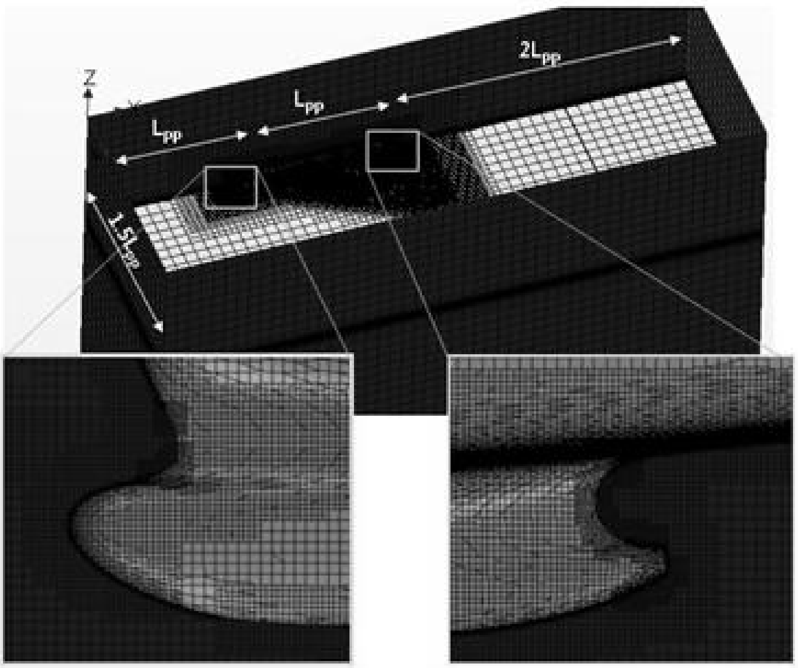

Figure 2. Simple example of size and form of fluid domain and grid details

8. RESULTS

In addition, the results obtained for all the conditions under which the hull under question was assessed: drafts and speeds. The following should be included in the report:

(1) One figure showing an example of one of the simulations showing the residuals. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc.;

(2) One figure showing an example of a convergence plot of the total resistance, viscous resistance, pressure resistance, propeller thrust. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc.;

(3) The following views of the flow are required with colour code as a minimum:
- Global view of the wave pattern with wave height
- Zoom view of the wave pattern at the bow and stern regions
- Views of the y+ values for the hull and appendages
- Views of the pressure coefficient for the hull and appendages
- Views of nominal wake distribution at the propeller plane
- In case propeller is fully modelled or in case an EET is considered, cross section views of flow past the propeller and EET device (normalized velocity and pressure at different cross sections)

Different examples on the views/results expected are shown below:

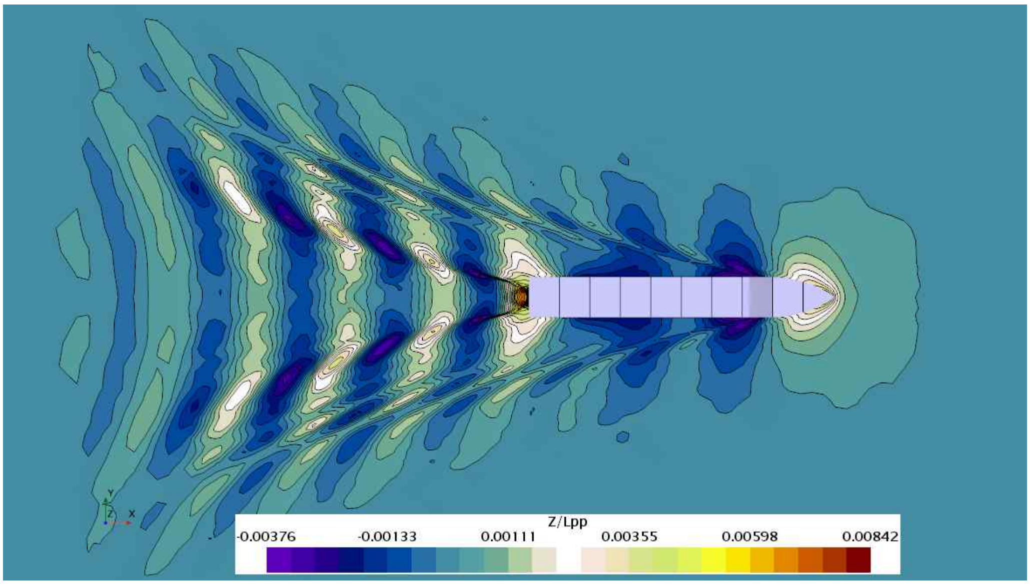

Figure 3. Wave-patterns

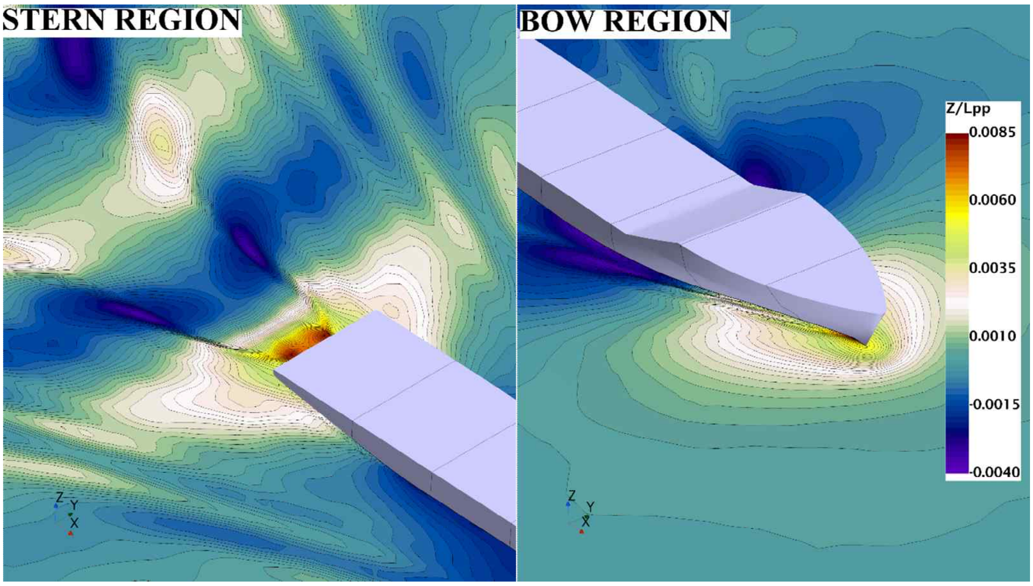

Figure 4. Zoom view of the wave-patterns around stem and stern

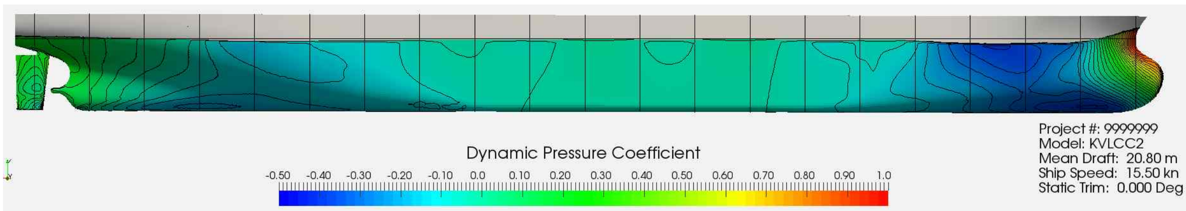

Figure 10. Distribution of the dynamic pressure coefficient along the hull form

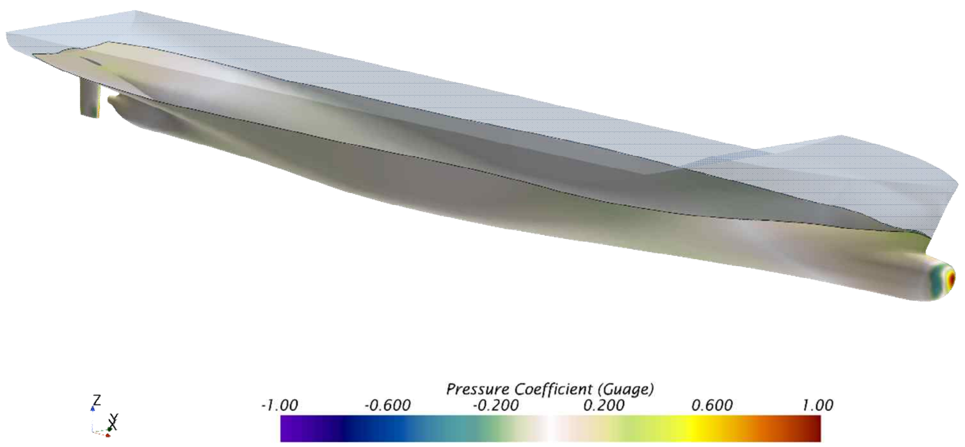

Figure 5. Distribution of the pressure coefficient on the wetted hull surface

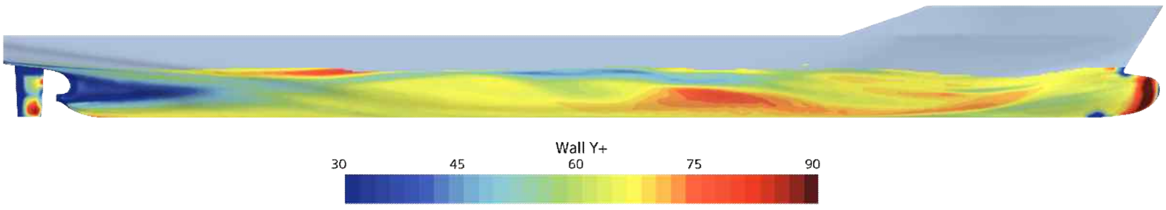

Figure 6. Distribution of Y+ values along the hull form

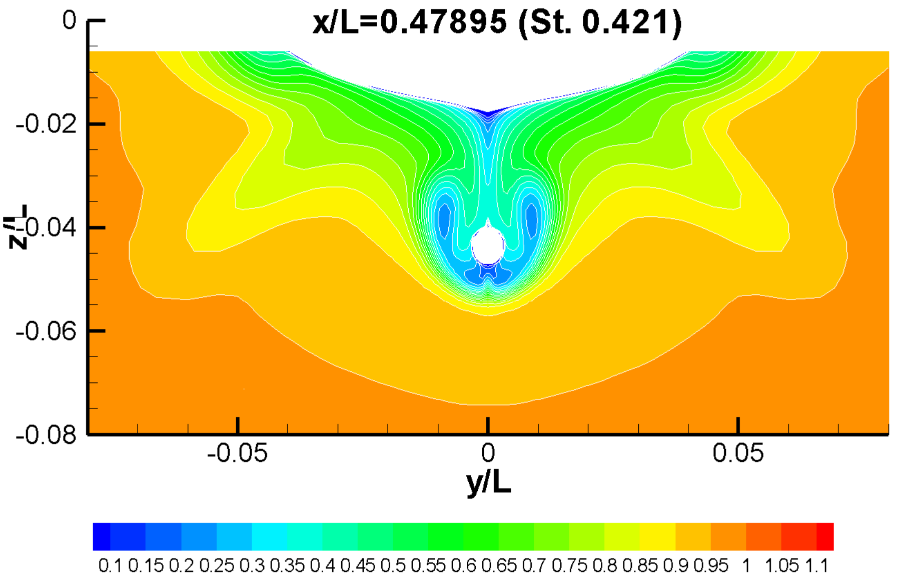

Figure 7. Distribution of non-dimensional x-velocity by a ship speed

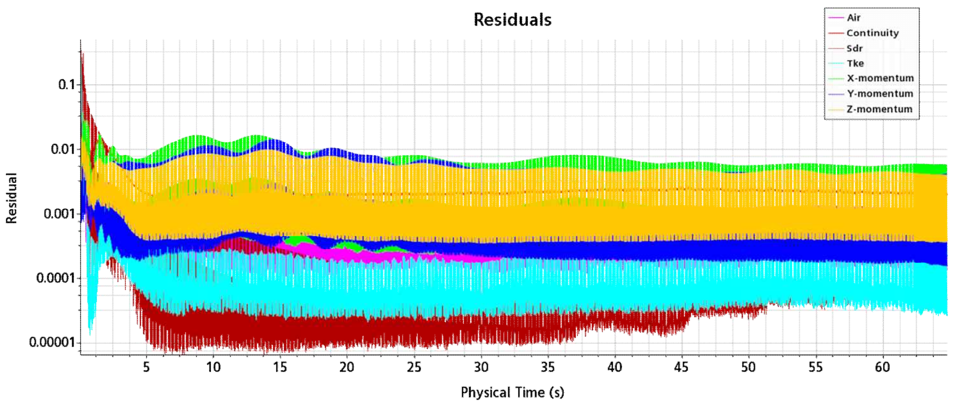

Figure 8. Convergence plot of numerical residuals

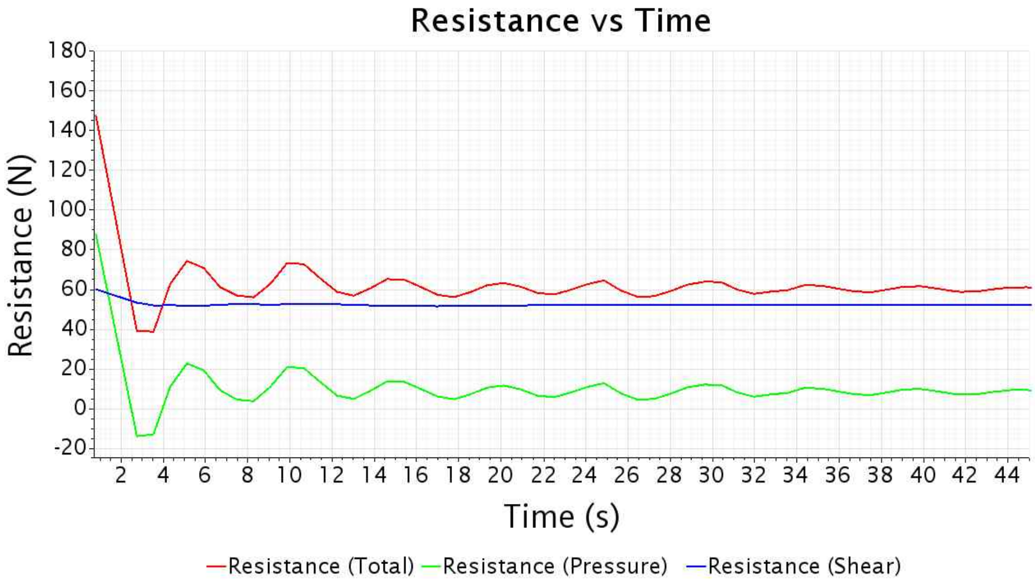

Figure 9. Convergence plot of main efforts

Summary of values obtained from simulations in a tabular format for all the drafts and speeds/power setting simulated:

(1) Ship resistance (total, viscous and pressure resistances)
(2) Thrust deduction factor (1-t)
(3) Effective wake factor (1-w)
(4) Propeller Thrust
(5) Propeller Torque
(6) Propeller efficiency
(7) Rotation Rate
(8) Delivered Power

9. VALIDATION ASSESSMENT

(1) This is to demonstrate that the values obtained are within reasonable and expected values. The goal is not to strictly validate the absolute values contained in the results but rather to validate that the final values and flow pattern obtained agree with physical reality.
(2) This should be performed with a qualitative assessment of the results and by demonstration using as supporting documentation quantitative reference values of the results obtained.
(3) This can be done by using a subset of the results (graphically and numerically) and justifying how they can be considered “as-expected”.

Guidelines on Numerical Calculations for the purpose of deriving the Vref in the framework of the EEXI Regulation

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