標題

IACS Recommendation No. 173 の制定について
（EEXI 関連）

ClassNK
テクニカル
インフォメーション

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各位

2021 年 6 月に開催された IMO 第 76 回海洋環境保護委員会（MEPC 76）において、EEXI 規制を導入するための MARPOL 条約 附属書 VI の改正（IMO 決議 MEPC.328(76)）が採択され、2022 年 11 月 1 日に発効いたしました。EEXI の計算及び認証等の要件を定めた IMO ガイドライン MEPC.350(78)並びに MEPC.351(78)が発行されており、基準船速（V_{ref}）を導出する方法として CFD 等の数値計算が認められています。IACS は数値計算をサポートするためのガイドラインを開発し、今般、IACS Recommendation No. 173 として制定しましたのでお知らせいたします。

本テクニカル・インフォメーションに記載の IMO の関連ガイドラインについては、弊会ホームページの下記より入手できます。
ホーム＞業務サービス＞条約関連＞エネルギー効率関連条約(EEXI)

なお、本件に関してご不明な点は、以下の部署にお問い合わせください。

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添付：

1. No. 173 Guidelines on Numerical Calculations for the purpose of deriving the V_{ref} in the framework of the EEXI Regulation

No. 173
(Nov 2022)

Guidelines on Numerical Calculations for the purpose of deriving the V_{ref} in the framework of the EEXI Regulation

1. Background

IMO resolutions MEPC.350(78) and MEPC. 351(78) considers Numerical Calculations as an acceptable way to derive the reference speed (V_{ref}) in the EEXI regulation framework. These guidelines have been developed to provide a methodology for deriving V_{ref} using numerical calculations.

2. Applicability

Numerical calculations methodology presented in these guidelines involves three (3) steps (which are detailed in section 5):

Step 1: Demonstration of qualification

Step 2: Validation/Calibration

Step 3: Calculation

This methodology can be applied to the following scenarios:

- In cases where a new speed power curve should be derived at the EEDI/EEXI draft in cases where the vessel has not been subjected to modifications.

- In case where the vessel has been subjected to modifications, the methodologies described here-after can still be used where the step 2 is computed with the original hull and the step 3 is performed on the modified hull.

3. Supporting Documentation/Guidelines

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 verifier.

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

4. Definitions

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.

ITTC website suggests that these guidelines have been deleted. They are however kept as they are referenced in the MEPC. 351(78).

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.

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 *Lpp*, *Cb*, displacement at Maximum Summer Load Draft, with similar bow shape (bulbous/straight bow, integrated bulbous bow, etc) and similar stern hull shape and arrangement with appendages.

Set of comparable ships are those with the similar[2] hull form, with the same number of shafts/propellers and with similar bow shape (bulbous bow, integrated bulbous bow, straight bow) and stern shape.

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.

5. Numerical Calculations Methodology

As per Resolution MEPC.334(76), 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 verifier. The methodology to be applied is as follows.

Step 1: Demonstration of qualifications

It should be demonstrated by the provider their ability to carry out CFD predictions. The companies may refer to the demonstration process as outlined in the ITTC 7.5-03-01-02, Rev.02, 2021 (referenced in MPEC. 351(78)), or an alternative methodology provided which is approved by the verifier. This demonstration should be performed against a reference "set of comparable ships" (see definition in section 4). Public domain hull forms and validation tests may be used, such as KCS, KVLCC1, KVLCC2, JBC, DTC, etc.

Step 2: Validation/Calibration

In case model test or sea trials are available, the numerical models used are to be calibrated against the parent hull.

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.

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

[2] Similar should be regarded same ship type. 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.

No. 173 (cont)

principles as outlined in PR38 Rev.3) and the final values are to account for roughness and appendages, where applicable.

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 (see definition in 4). The validation can be demonstrated both in model and full scale.

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 these guidelines, it is understood that the word validation and calibration are intended to have similar meaning. As further outlined in these guidelines, IACS 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.

Step 3: Calculation

The calculation of the new reference speed or speed power curve is performed for the target ship. The same numerical calculation procedure as in step 2 should be used. Additionally, the results are to be corrected to model test or sea trial conditions using a calibration factor obtained from step 2.

Based on the above steps 2 and 3, the options are summarized in the chart below and detailed in the following sections.

Option 1 – Calibrated Sea Trials or Model Tests of Parent Hull	*Option 2 – Calibrated CFD Model Tests of Similar Ship*	*Option 3 – Calibrated CFD with Sea Trials of Set of Comparable Ships*
• Calibration Factor based on parent hull • Defined by reproducing the model test or sea trials (following ISO 15016:2002) at the draft closest to the EEDI/EEXI one. • The calibration factor percentage is limited by the verifier.	• Calibration Factor based on a similar ship • Defined by reproducing model tests of a similar ship. • Calibration factor limited to 5%, without justification	• Calibration Factor based on a set of comparable ships (at least 10 combinations of draft and vessels) • Defined by reproducing sea trials for a set of comparable ships. • Calibration factor is limited to 5%, without justification • Sea trials to be conducted following ISO 15016:2002 or alternative if approved by verifier

5.1 Option 1: Calibrated CFD with sea trials or model tests of parent hull

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. 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 verifier.

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.

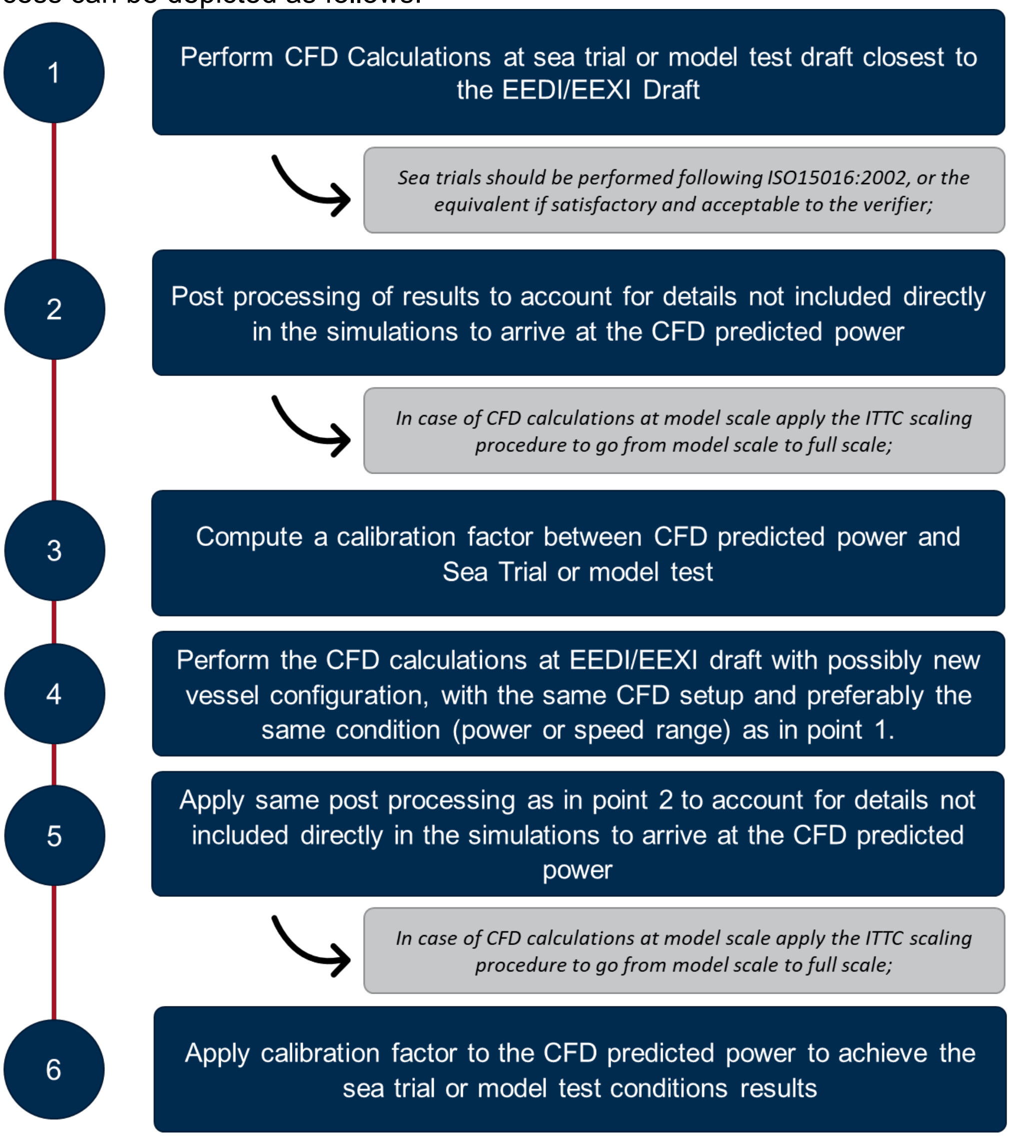
In case of model scale simulations, the results need to be extrapolated to full scale following ITTC 78 (or deviations of it, following the principles as outlined in PR38 Rev. 3). As far as possible the conditions as in the model test are to be followed (Ca, ITTC procedure, how appendages have been accounted for, etc).

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

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 vs Power Curve.

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.

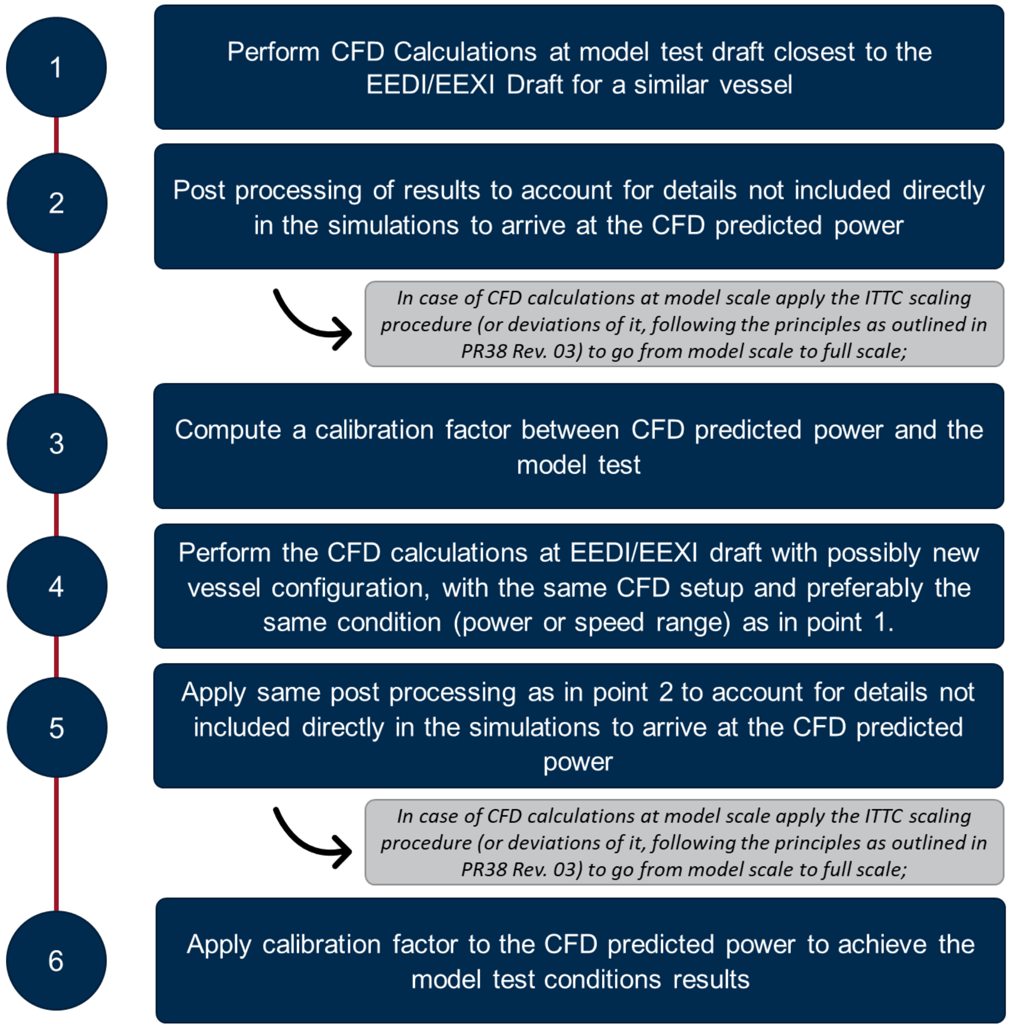
The process can be depicted as follows:



No. 173 (cont)

5.2 Option 2: Calibrated CFD with model test of similar ship

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. If the achieved calibration factor lies between 0.95 and 1.05, this can be considered as acceptable to the verifier 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 verifier. The definition of calibration factor can be found in Section 4.



5.3 Option 3 – Calibrated CFD with sea trials of a set of comparable ships

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. Sea trial results that have been scaled from ballast draft to laden draft based on model test results CANNOT be used. Sea trials are to be performed as per ISO15016:2002, or the equivalent if satisfactory and acceptable to the verifier. Sea trials in ballast and laden condition should be included in the assessment.

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 following the definition in section 4 and the methodology should be approved by the verifier. The individual

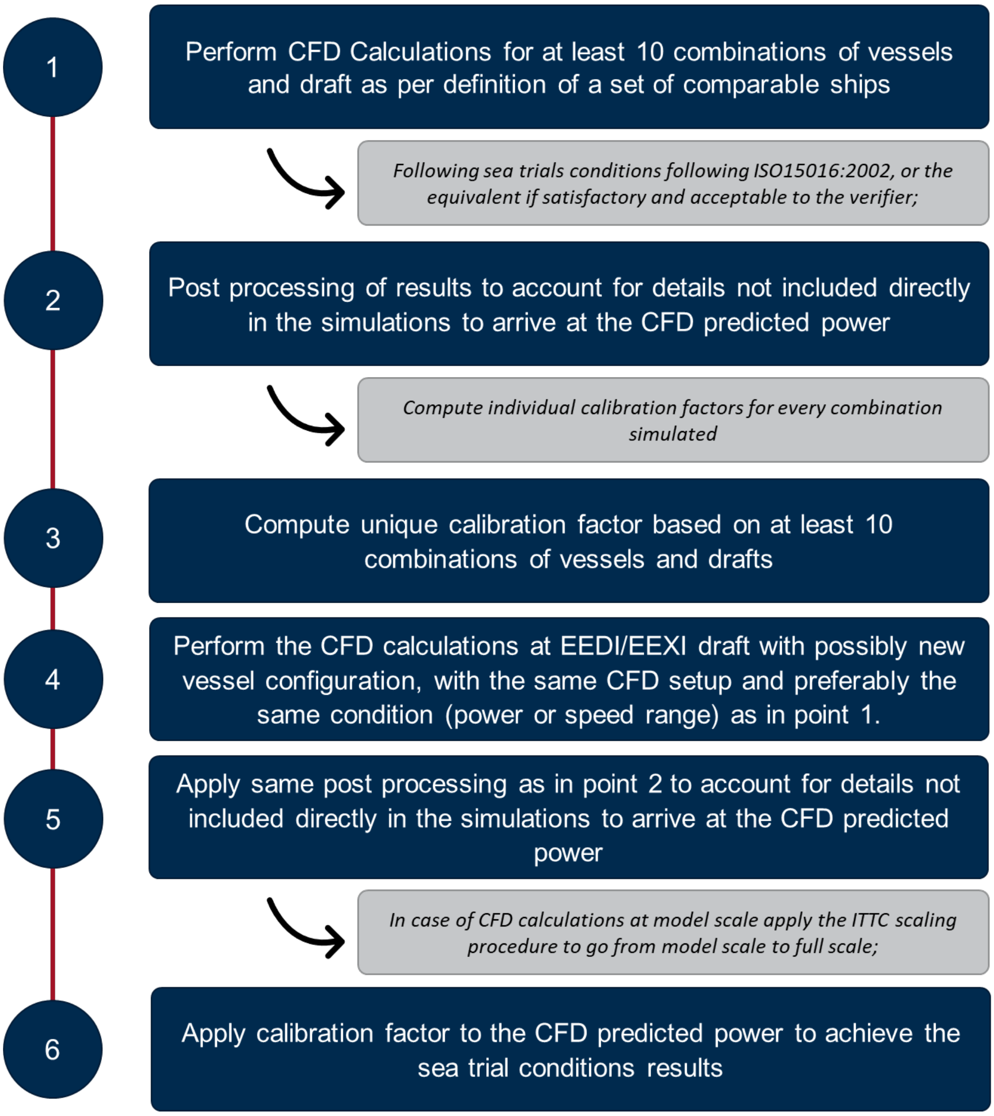
No. 173 (cont)

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 verifier 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 verifier.

The *Lpp*, 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. 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 the verifier is to verify the accuracy and representativeness of the dataset used to derive the calibration factor, i.e., that these are evenly spread across the range of *Lpp*, displacement and *Cb*. It is also to be verified that at least 2 vessels of the database are between 0.85 and 1.15 *Lpp* of the target ship.

With option 3, the provider is exempted from demonstrating qualifications as per section 7.2. All the simulations contained in the database are to be done following at best the requirements outlined in these guidelines in section 6. The verifier may require access to the details of the calculations included in the database to derive the calibration factor.



6 Technical Aspects

Technical aspects to be applied to the simulations are detailed in this section. These aspects are to be covered in the numerical calculations to be reviewed by the verifier.

6.1 Scale

Technically, simulations can be performed both at model and full scale. The following preference should be given to each of the options listed in section 5. 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 verifier. For the other options, both scales may be used. The validation/calibration and calculation need to be conducted at the same scale.

6.2 Numerical Modelling

Information on the required numerical modelling is provided in the following table.

Table 1 – Details on the required numerical modelling level.

Item	Value
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.
Degrees of freedom	Model should at least be free in heave and pitch.
Propeller modelling	As a minimum requirement, actuator Disk. Note that for Energy Efficiency Technologies, other requirements are set in section 8.
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 simulations, 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”.
Y+ values	ITTC 7.5-03-02-03 to be followed

No. 173 (cont)

7. Reporting Requirements

The sections below detail the 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.

7.1 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.

7.2 Qualifications

Reference is made to the ITTC 7.5-03-01-02 Quality Assurance in Ship CFD Applications, Section 5. Companies 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.

This demonstration may include the ship types under consideration, referring to the definition of “set of comparable ships” as per section 4. It remains at the discretion of the verifier to assess if the documentation provided is sufficient to ensure the ability of the company to deliver the numerical calculations.

7.3 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:

- Model test report
- Sea trial report
- Hull drawings
- General arrangement
- Propeller drawings

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

7.4 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:

- Ship name
- IMO Number and/or Hull Number
- Vessel type
- Design draft
- Lightweight and displacement
- EEXI draft

No. 173 (cont)

- Main Engine Power (SMCR, NCR)
- Length between perpendiculars (LPP)
- Beam molded (B)
- Depth (D)
- Propeller data:
  - Diameter
  - Number of blades
  - Rotation direction
  - Expanded area ratio
  - Main dimensions of the hub
  - Chord length, maximum thickness, and pitch ratio at a reference radius (usually 0.7 R), if available.
  - ESD type, if applied

7.5 CFD Software

A section containing a description of the CFD software used and the version of the same. This can be part of the Qualifications step as detailed in section 7.2.

7.6 CFD Model Geometry and Mesh

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).

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:

- LOA & LPP
- Molded beam (B)
- Depth (D)
- Displacement at the different drafts under consideration in the study
- Wetted Surface including rudder and with the bare hull
- LCB in % of LPP
- VCB from Baseline

It is of the verifiers responsibility to agree that the vessel being used in the numerical model faithfully represents the actual hull under consideration. To support such, different views of the model geometry are to be provided. Verifier may request comparative views between construction, lines plan and the 3D CFD model.

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 verifier. Such convergence curve should contain at least 3 discrete mesh sizes.

In addition, the report should include the following information:

- 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.

- Different views of the mesh covering different aspects:
  - Boundary layer mesh for different parts of the hull if they differ
  - Close up views of the mesh around key parts of the hull: bow, aft, transom and appendages.

7.7 CFD Set-up

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

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

7.8 Validation Assessment

A validation assessment procedure may be performed by the provider. 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.

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

7.9 Post-processing and Results

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).

No. 173 (cont)

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:

- 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.

- 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:
    - 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
    - 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)

- Summary of values obtained from simulations
    - Ship resistance (total, viscous and pressure resistances)
    - Thrust deduction factor (1+t)
    - Wake deduction factor (1+w)
    - Propeller Thrust
    - Propeller Torque
    - Propeller efficiency
    - Rotation Rate
    - Delivered Power

8. Consideration of Energy Efficiency Technologies

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 these guidelines:

1. Air Lubrication (EET-B)

2. Hull painting and coatings (EET-A)

In the future, these 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 these guidelines.

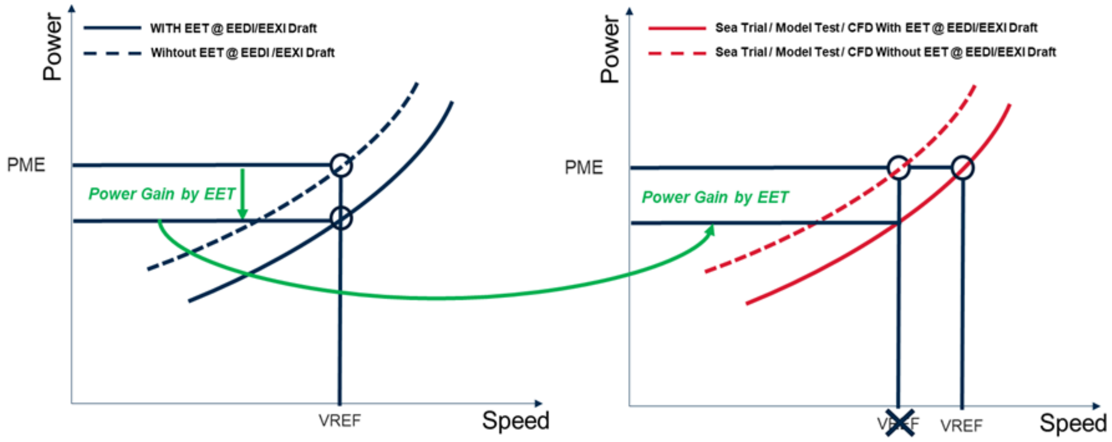
The procedure suggested to be applied relies on finding the improvements in power due to the addition of the EET and applying these as a correction factor on previously already obtained speed power curves (from sea trials, model test or other CFD calculations). These power improvements are to be calculated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

No. 173 (cont)

3. Apply the gains on top of the final Speed Power Curve as derived following options in section 5, or as previously available from existing sea trials and/or model tests.



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 section 3

   - Free-surface: the free-surface may not be modelled, if considered acceptable to the verifier. 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.

   - Hull Geometry: the hull geometry should be fully modelled in the Numerical Simulation following the consideration in section 6 with the following notes:

     - 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".

     - 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.

2. That the qualifications as per section 7.2 are demonstrated, in this case for cases where an Energy Efficiency Technology was considered.

3. 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.

4. That the propeller RPM without EET is compared to the expected values as in model test or sea trials. The differences are expected to be within reasonable thresholds, to be defined and agreed with the verifier.

No. 173 (cont)

5. In absence of the geometry of the propeller for the target hull, a replacement propeller may be rebuilt 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:

   - If the Kt Kq 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 range[3] (comparison on the basis Kt, 10Kq and η_O)

   - If the Kt Kq 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 operating range[3] (comparison on the basis Kt, 10Kq and η_O)

   - The final geometry has the same features (diameter, number of blades, hub diameter, etc) 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:

	Replacement Propeller	Target Propeller
Diameter		
Number of blades		
Rotation Direction		
Expanded Area Ratio		
Hub diameter		
Chord Length		
Max. thickness		
Pitch Ratio at 0.7R		

6. That the mesh used in numerical model has its convergence demonstrated with the inclusion of the propeller or the alternative model as per point 3.

[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.

No. 173 (cont)

9. Propeller Open Water Simulations

As per 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:

1. That the same definition of numerical calculation is applied as in section 3.

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 section 6 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 section 7.6, 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 η_O).

[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.

Appendix 1 – Example of Template Report

INTRODUCTION

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 IACS Guidelines and the most updated 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 MEPC. 350(78) 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.

QUALIFICATIONS

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

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 #	Year	Description
1	2013	
2	2014	
3	2015	
4	2016	
5	2016	
…	…	

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

Project #	Year	Ship type	Scale
1	2013	*Tanker 59kDWT*	*Full Scale*
2	2014		
3	2015		
4	2016		
5	2016		
…	…		

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 IACS Guidelines.

Project #	Year	Scale
1	2013	
2	2014	
3	2015	
4	2016	
5	2016	
…	…	

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 Number and/or Name	Description

CFD SOFTWARE DESCRIPTION

Short Description of the CFD software used in the simulations, account for the software and version being used alongside a general description of the same.

VESSEL DESCRIPTION

The vessel characteristics are found below:

Vessel Name	
IMO Number	
Vessel Type	
MCR x RPM	
DWT	
LWT	

No. 173 (cont)

Design Draft	
EEXI/EEDI Draft	
LPP	
Beam molded (B)	
Depth (D)	

The propeller characteristics are found below:

Diameter	
Number of blades	
Rotation Direction	
Expanded Area Ratio	
Hub diameter	
Chord Length	
Max. thickness	
Pitch Ratio at 0.7R	

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 calculation.

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

NUMERICAL MODEL SET-UP DESCRIPTION

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

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

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:

- 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;

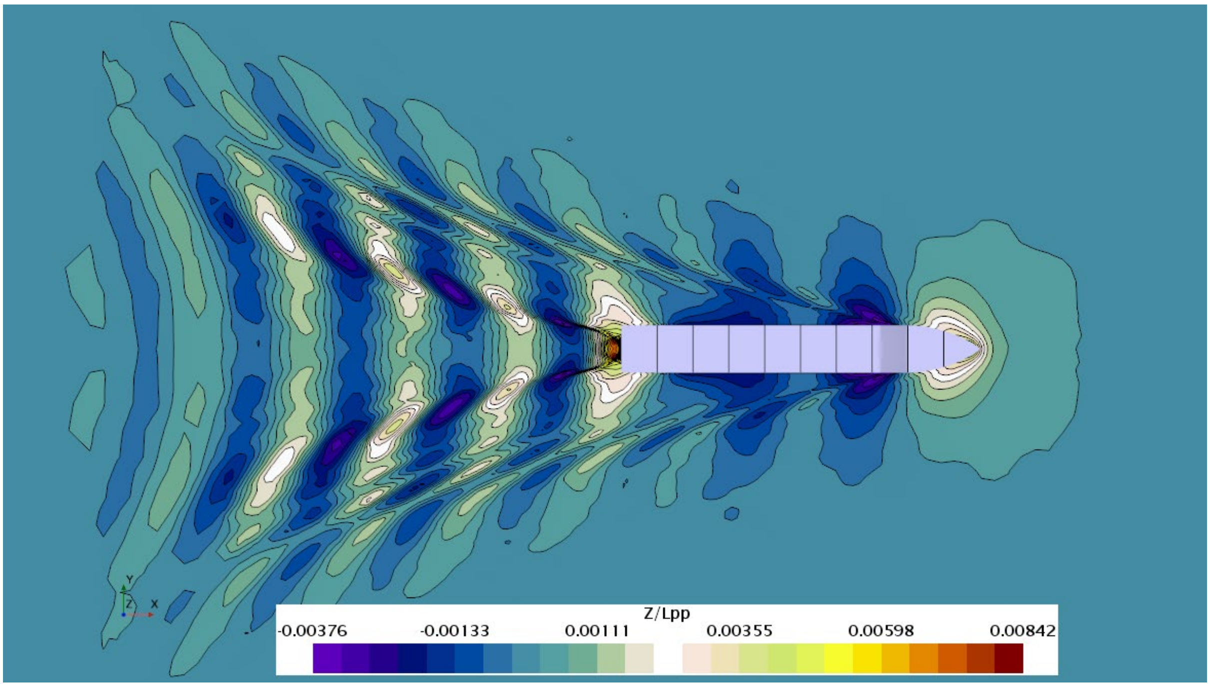
- One figure showing an example of a convergence plot of the total resistance, viscous resistance, pressure resistance, propeller thrust. Minimum of one plot per type of simulations performed: resistance, self-propulsion, open water curves, etc;

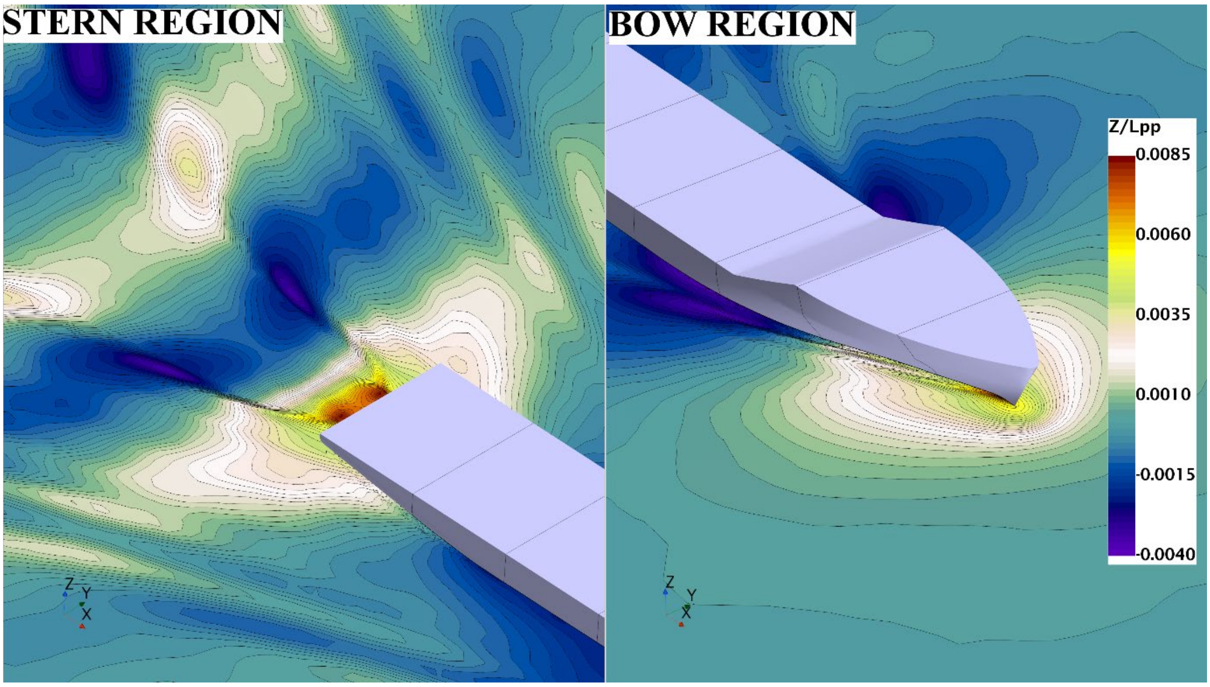
- The following views of the flow are required with colour code as a minimum:
  - Global view of the wave pattern with wave height
  - Zoom view of the wave pattern at the bow and stern regions
  - Views of the y+ values for the hull and appendages
  - Views of the pressure coefficient for the hull and appendages
  - 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)

No. 173 (cont)

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

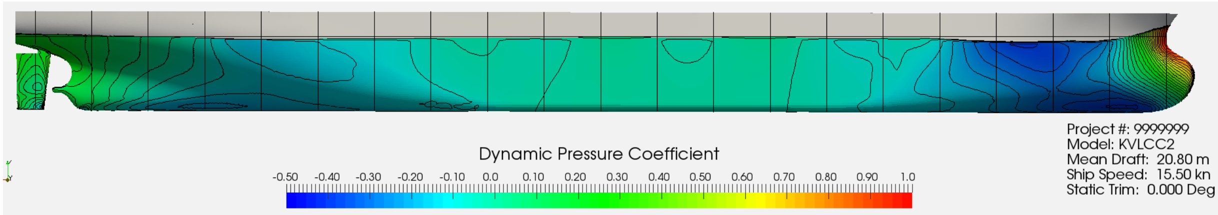
Wave pattern:

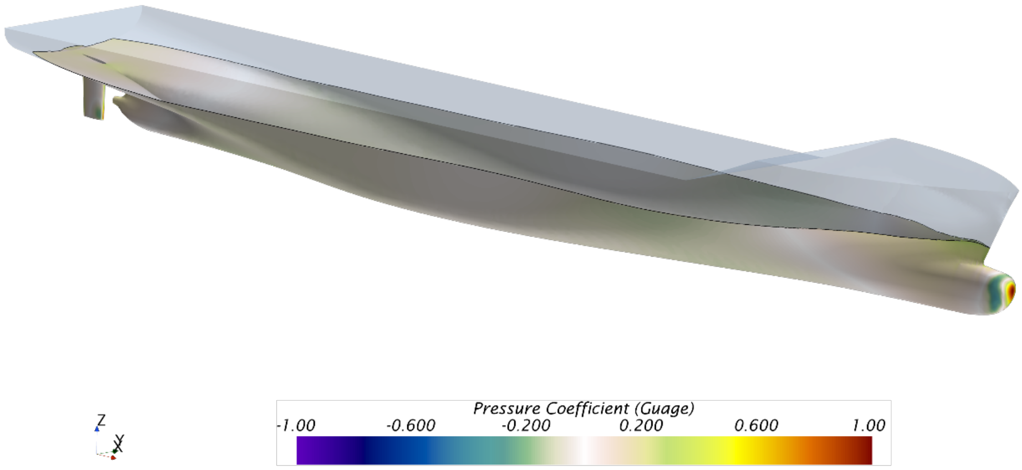




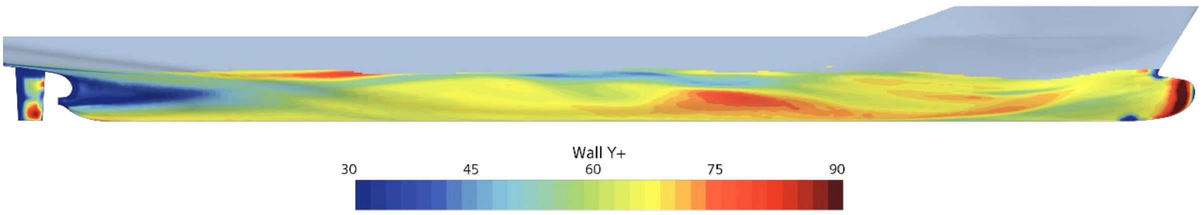
No. 173
(cont)

Dynamic Pressure field:

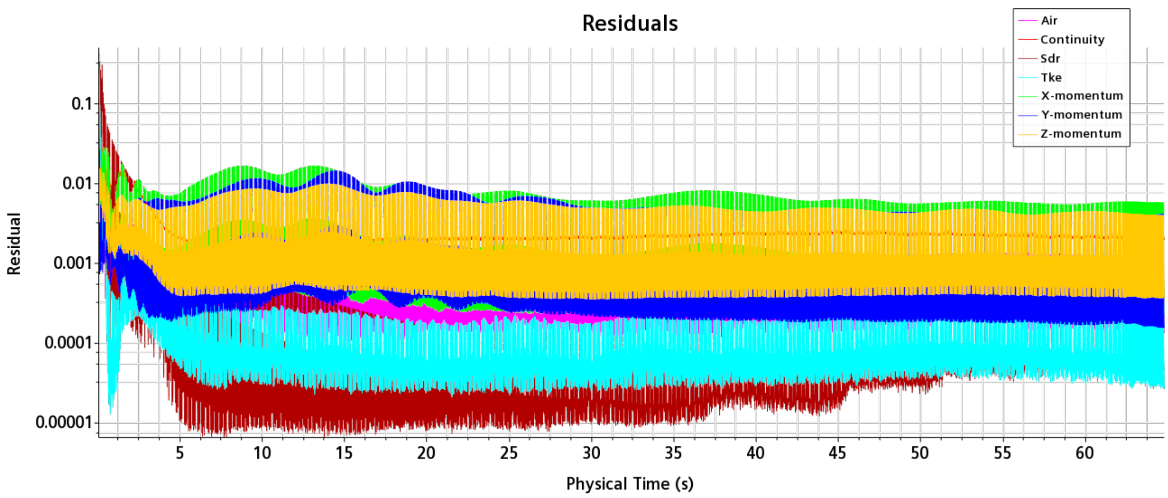




Y+ Values

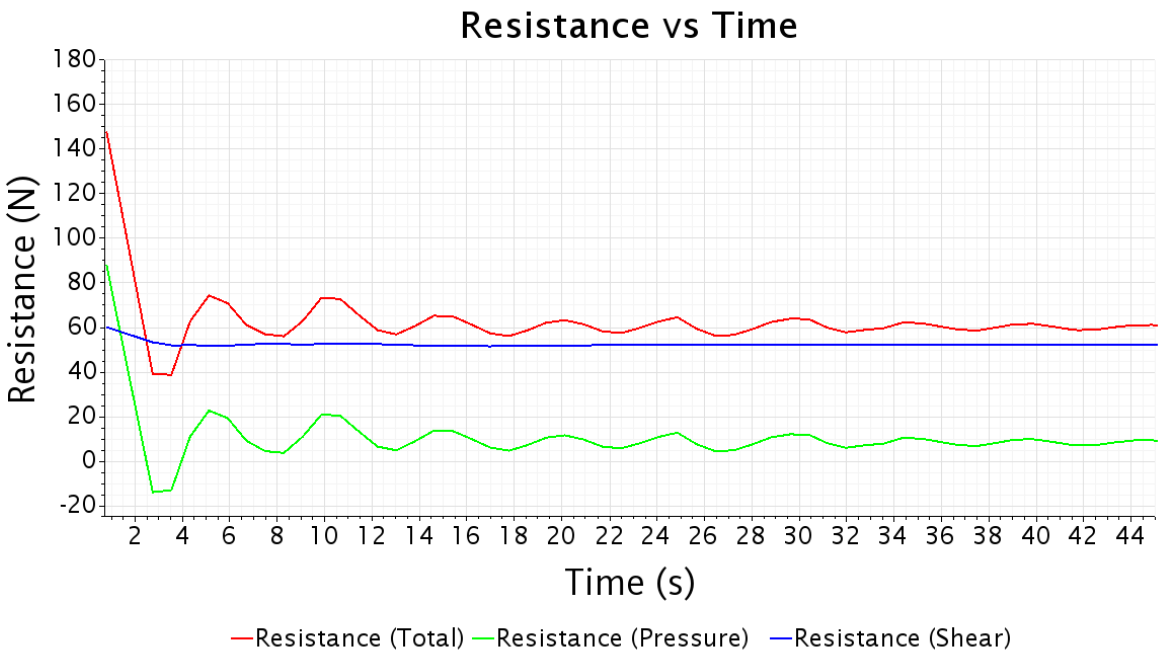


Convergence Plot of Numerical Residuals



No. 173 (cont)

Convergence Plot of main Efforts



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

- Ship resistance (total, viscous and pressure resistances)
- Thrust deduction factor (1+t)
- Wake deduction factor (1+w)
- Propeller Thrust
- Propeller Torque
- Propeller efficiency
- Rotation Rate
- Delivered Power

VALIDATION ASSESSMENT

A validation assessment procedure may be presented. This is to demonstrate that the values obtained are within reasonable and expected values. This can be done by using a subset of the results (graphically and numerically) and justifying how they can be considered "as-expected".

End of Document