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GUIDELINES FOR VERIFICATION AND SURVEY OF LOW FRICTION PERFORMANCE OF HULL COATINGS

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CHAPTER 1   GENERAL

1.1   General requirements

1.1.1 The Guidelines specify relevant requirements for verification of the performance of low-friction coatings, ship speed prediction for ships applying low-friction coatings, survey of coatings of ships in service, and management of surface coatings of the hull during the operation of the ship.

1.1.2 The Guidelines apply to sea-going newbuildings applying low-friction coating techniques below the waterline in order to reduce EEDI, EEXI or CII. The Guidelines also apply to the existing repainted sea-going ships.

1.1.3 The Guidelines mainly apply to the verification and survey of the low-friction performance of self-polishing coatings(SPC) and fouling-release coatings(FRC). Considering that the low-friction coating technique is still in the phase of development, the calculation method, evaluation standard, survey and test methods of other types of coatings (e.g.:bio-mimetic coating) may be accepted as equivalent methods if sufficient theoretic basis, test results, user experience or recognized standards are provided with the consent of ISC.

1.1.4 Sea-going ships applying low-friction coatings are also to comply with the applicable requirements of ISC Rules for Classification of Sea-going Steel Ships and ISC Guidelines for Survey of anti-fouling Systems on Ships in addition to the requirements of the Guidelines.

1.2   Definitions

1.2.1   For the purposes of the Guidelines, the terms are defined as follows:

(1) **Low-friction coating technniques** refer to techniques by applying appropriate coatings on the surface of hull below the waterline to reduce friction so as to achieve energy efficiency and reduction of emission.

(2) **Initial coating surface roughness** refers to the roughness derived from surface irregularities in the coating itself in the initial stage of completion of coating application.

(3) An **Applicant** refers to a shipowner or a shipyard applying for the survey of low-friction performance of coating by ISC.

(4) **Low-friction durability of coating** refers to the performance of coating to maintain the low-friction characteristic within 5 or more years of expected life.

(5) **Rt50** refers to a measure of the min-max peak over a 50 mm length of the hull.

(6) **MHR** refers to mean hull roughness of each patch. Sections of equal length are to be divided according to the ship length and the hull within these sections is to be divided into 100 to 120 patches and at least twelve Rt50 values per patch are to be measured by instrument. Surface damaged areas and welds are to be avoided during measurement.

(7) **AHR** refers to average hull roughness value, resulted from the average of about 100 to 120 MHR values.

1.2.2   The abbreviations used in the Guidelines are as follows:

(1) ROV：Remotely Operated Vehicle；

(2) HCMP：Hull Coating Management Plan；

(3) LFHC：Low Friction Hull Coating；

(4) ITTC:International Towing Tank Conference；

(5) CFD:Computational Fluid Dynamics；

(6) RANS:Reynolds-average Navier-Stokes equations.

1.3 Class notations

1.3.1 The class notation LFHC (FxMy) may be assigned to ships on which low-friction coatings are applied provided the requirements of the Guidelines are met.

(1) Fx, representing hull roughness, reflects the coating surface roughness during the delivery stage of the newbuildings and after the completion of re-coating of the existing ships, where x has levels according to the corresponding standards in Table 1.3.1. The class notation is to be subject to the speed prediction and verification of Chapter 3 of the Guidelines and will be graded into different levels after full-scale data measurement according to Chapter 4 of the Guidelines.

(2) My, representing hull coating low-friction durability, reflects the low-friction durability level during the operation of ships, where y has three levels according to the corresponding standards in Table 1.3.1 and represents the comprehensive performance of shallow sea soak test and dynamic test. The class notation will be graded into different levels based on the rating acquired from the test carried out according to Chapter 2 of the Guidelines.

Corresponding level of class notation **Table 1.3.1**

Roughness mark for hull coating	Roughness level
F1	110μm < AHR ≤140μm
F2	80μm< AHR ≤110μm
F3	AHR≤80μm
Low-friction resistance mark for hull coating	Score
M1	85≤M＜90
M2	90≤M＜93
M3	≥93

1.3.2 For newbuildings to which 2.3.2 and 4.3.2 of ISC Rules for Green-Eco Ships apply, if low-friction coating is adopted, prediction and verification of navigation speed are to be carried out according to Chapter 3 of the Guidelines and included in the calculation of Attained EEDI of the ship.

1.3.3 For in-service ships to which 2.3.3 of ISC Rules for Green-Eco Ships applies, if low-friction coating is adopted, prediction and verification of navigation speed are to be carried out according to Chapter 3 of the Guidelines and included in the calculation of Attained EEXI of the ship.

1.4 Plans and documents

1.4.1 The following plans and documents are to be submitted for examination when applying for the class notation LFHC (FxMy):

(1) paint product specifications or equivalent documents;
(2) coating application process;
(3) low-friction durability test report of coating;
(4) navigation speed prediction report;
(5) coating arrangement of ships;
(6) roughness measurement report for hull coating;
(7) hull coating management plan;
(8) other plans and documents as deemed necessary by ISC.

1.5 Surveys

1.5.1 Coatings with low-friction performance are to be subject to works approval according to Chapter 3, PART ONE of ISC Rules for Classification of Sea-going Steel Ships and relevant requirements of Chapter 2 of the Guidelines are to be met at the same time.

1.5.2 Construction survey includes the initial survey of the coating of newbuildings and modification survey of coating of the existing ships, which are to comply with relevant requirements of Chapter 4 of the Guidelines. In-service survey of ships is to comply with relevant requirements of Chapter 6 of the Guidelines.

1.5.3 The verification of navigation speed of ships applying low-friction coating is to meet relevant requirements of Guidelines on Calculation and Verification of the Energy Efficiency Design Index(EEDI) of International Sea-going Ships, Guidelines for Calculation and Verification of the Energy Efficiency Design Index (EEDI) of Ships Engaged on Domestic Voyages and Guidelines on Calculation and Verification of the Attained Energy Efficiency Existing Ship Index (EEXI).

CHAPTER 2 VERIFICATION OF LOW-FRICTION PERFORMANCE OF COATINGS

2.1 General requirements

2.1.1 This Chapter specifies the requirements for verification of low-friction performance of ships applying for the class notation LFHC (FxMy).

2.1.2 The paint manufacturer is to provide the product specifications to clarify the coating process and hull roughness level after the completion of application of coating.

2.1.3 The low-friction durability of coating is to be tested according to 2.2 of this Chapter or ISO standard laboratory test methods or other equivalent test methods.

2.2 Verification of low-friction performance

2.2.1 For the purposes of the Guidelines, paints are divided into the following two categories:

(1) Type I (self-polishing type): surface paints made with organic co-polymer as base material, having self-polishing characteristic during navigation.

(2) Type II (fouling-release type): hydrophobic surface, hydrophilic surface or amphipathic surface paints formed on the basis of advanced polymer techniques.

2.2.2 Low-friction durability test of coatings

2.2.2.1 The low-friction durability test includes shallow sea soak test and dynamic test. The selection, examination and preparation of test samples are to meet the requirements of GB/T 6822 respectively.

2.2.2.2 The low-friction durability test is to be carried out by an test organization accepted by ISC.

2.2.2.3 Requirements for shallow sea soak test are as follows:

The test is to be carried out according to the requirements of GB/T 5370. The test methods for shallow sea soak test with type I and type II paints are: for paints containing biocide, the test is to last for 3 marine organism growing seasons and for biocide free paints, the test is to last for 1 marine organism growing season; each paint is to be examined and rated at least once half a year. After the test, the sample is to be rated for its performance into three levels: S1, S2 and S3 according to the rating standard. See Table 2.2.2.4.

2.2.2.4 Requirements for dynamic test are as follows:

(1) Type I: the sample plate of self-polishing anti-fouling coating is to be tested with reference to GB/T 7789. The linear velocity for the test is 18±0.5 knots or other agreed velocity. After the continuous operation of the sample plate, which amounts to navigation of 7408±92 km (4000±50) n mile, the sample plate is to be stopped and checked for the surface condition. Then a shallow sea soak test lasting 1 cycle (30 days) is to be carried out. After the end of each cycle, the change of film thickness of anti-fouling coating is to be tested by a laser thickness measurement device or an optical microscope. Eight circles of tests are to be carried out and the performance of sample plate is to be scored according to GB/T 5370 and the results will be graded into three levels according to the rating standard, namely D1, D2 and D3 respectively. See Table 2.2.2.

(2) Type II: put the sample plate into a test floating raft to carry out the shallow sea soak test for at least 45 days (determined based on the product specifications and the applicable longest port static soak time is to be indicated in the check result). Check and record the coverage area of the hard shell organisms (barnacle, hard-shell bryozoa, coiled tube worm etc.) attached to the surface of sample plate and other types of attached organisms, take photos. Then, move the sample plate to a

dynamic test device and the linear velocity of the surface of sample plate is to be adjusted to 18±0.5 knots or other agreed velocity. After 3 days continuous operation of sample plate, the coverage area of the attached organism (barnacle, hard-shell bryozoa, coiled tube worm etc.) left on the surface of sample plate is to be checked and recorded with photos taken. This is one cycle of the dynamic test. Eight test cycles are to be carried out and the anti-fouling performance of the sample plate and the physical condition of anti-fouling coating film are to be rated according to GB/T 5370. The sample plate with the lowest score is to be taken for the rating of final overall performance. There are three levels according to the rating, namely D1, D2 and D3 respectively. See Table 2.2.2.

Rating for low-friction durability paint test Table 2.2.2

		Type I (self-polishing or corrosive type)	Type II (fouling release type)
Test name	Rating	Score	Score
Shallow sea soak test	S1	≥85 and <90	≥85 and <90
	S2	≥90 and <93	≥90 and <93
	S3	≥93	≥93
Dynamic test	D1	≥85 and <90	≥85 and <90
	D2	≥90 and <93	≥90 and <93
	D3	≥93	≥93
Overall	M	Σ(0.8*S+0.2*D)	

CHAPTER 3 SPEED PREDICTION AND VERIFICATION OF SHIPS

3.1 General requirements

3.1.1 This Chapter applies to the speed prediction and verification of sea-going newbuildings applying low-friction coating techniques and in-service ships undergone modification of coating.

3.1.2 This Chapter aims to provide relevant verification guidance for verification of the influence of low-friction performance of coating on ship resistance and speed for ships applying for including the energy efficiency effect generated by low-friction coating techniques into the Attained EEDI/EEXI.

3.1.3 Since the application of low-friction coating techniques will change the speed-power curve, the ship is to regain the speed-power curve once the techniques is applied.

3.2 Speed prediction

3.2.1 Speed prediction based on model test

3.2.1.1 The testing organization is in generally to be the member of ITTC and the test procedure is to meet relevant procedures of ITTC. The testing organization is also to be subject to ISO 9001 or equivalent quality system certification. The qualification and the service of the test and resistance prediction personnel are to be effectively managed and monitored. For resistance test procedures, refer to ITTC 7.5-02-02-01.

3.2.1.2 The Model-Ship correlation method adopted by the testing organization is to be documented and ITTC 7.5-02-03-01.4 is to be taken for reference.

3.2.1.3 Ship friction resistance may be corrected by means of the method of correction of the predicted value of friction resistance based on hull coating surface roughness provided in the product specifications or other reasonable equivalent methods. If the predicted value of friction resistance is corrected based on the hull coating surface roughness, 1.1.2 and 1.2.3 of Annex 1 may be taken as reference for prediction method. If other methods are adopted, a complete prediction calculation report is to be submitted to ISC for review.

3.2.1.4 The full-scale speed prediction calculations based on the model test is at least to include the following supporting information:

(1) model test report;

(2) full-scale propeller open water characteristic data;

(3) paint product specifications (including surface roughness parameters).

3.2.1.5 After the overall resistance of ship is corrected, the full-scale wake fraction and propeller advance speed coefficient are to be recalculated to obtain the new speed-power curve. Refer to the calculation methods in 1.1.6 and 1.2.4 of Appendix 1 for details.

3.2.2 Speed prediction based on CFD calculation

3.2.2.1 Basic requirements for CFD calculation

(1) CFD calculation is to comply with relevant requirements of ITTC 7.5-03-01-02 and ITTC 7.5-03-01-04.

(2) The applicability of CFD is to be determined according to the relevant requirements of the Guidelines on Calculation and Verification of the Energy Efficiency Design Index(EEDI) of International Sea-going Ships, the Guidelines for Calculation and Verification of the Energy Efficiency Design Index (EEDI) of Ships Engaged on Domestic Voyages and the Guidelines on

Calculation and Verification of the Attained Energy Efficiency Existing Ship Index (EEXI).

(3) The accuracy of the numerical method adopted by CFD is to be verified by comparing the CFD results of the parent ship, sister ship or similar ship with the results of model test or full-scale sea trial. The acquisition of the sea trail result used for comparison is to comply with the latest version of ISO 15016 or equivalent standards. The accuracy of CFD calculation method is to be represented by the calibration coefficient which is the ratio of the result of numerical calculation of the parent ship, sister ship or similar ship to the result of model test or full-scale sea trial in the same condition. The value to be between 0.95 and 1.05 (inclusive).

(4) For speed-resistance curve of ships with conventional model test result, the calibration coefficient may be taken as the average value of the ratio of at least 4 resistance points. For ships without conventional model test result, the accuracy of numerical method is to be verified by comparing with the sea trial result. For speed-power curve, the calibration coefficient is to be taken as the mean ratio of at least 4 power points (evenly distributed as far as possible, including 75% MCR operating point) between 65% MCR and 100% MCR (inclusive).

(5) In order to obtain a complete speed-power curve, the number of operating points for CFD calculation on the same curve is not to be less than the number of sampling points for model tests.

(6) The calculation report is to be submitted for review. For the report format, refer to Appendix 7.

3.2.2.2 Full-scale resistance prediction based on model scale CFD calculation

(1) The effect of roughness is not needed to be considered in the model scale CFD calculation and an extrapolation to full scale ship with reference to ITTC specifications according to 3.2.1 is to be used and documented. Length between the perpendiculars of ship model for CFD calculation is not to be less than 6 m.

(2) The method adopted in CFD calculation report and the conversion method extrapolated to the full-scale ship are to be fully consistent with the method used to verify the accuracy of the existing method provided in the report. The calculation result is to be corrected by the calibration coefficient. Considering that each resistance point/power point has different calibration coefficient, each resistance point/power point is to be corrected by its own calibration coefficient.

3.2.2.3 Ship resistance prediction based on full-scale CFD calculation

(1) The verified CFD model calculation method and parameters are kept unchanged in full-scale CFD calculation, and surface roughness parameters are corrected according to the coating surface roughness provided in the product specifications so as to calculate the full-scale resistance with the resistance reduction effect of coating being included.

(2) At present, there are two methods which have included roughness effect during RANS calculation:

① roughness is considered in wall function (applicable only when wall function is used);

② by adapting to turbulence boundary condition, e.g. k-ω model.

3.2.2.4 Full-scale speed prediction based on CFD

(1) The following documents are required:

① CFD calculation report;

② data on full-scale propeller open water characteristic;

③ paint product specifications (if roughness method is adopted to predict speed, coating roughness parameters are to be provided in product specifications).

(2) After the overall resistance of the ship is corrected, the full-scale wake fraction and propeller advance speed coefficient are to be recalculated so as to obtain the new speed-power curve. Refer to the calculation methods in 1.1.6 and 1.2.4 of Appendix 1 for details.

3.3 Speed verification

3.3.1 Preliminary verification

3.3.1.1 The preliminary verification of EEDI speed of ships engaged on international voyages is to comply with relevant requirements for preliminary verification in Chapter 4 of the Guidelines on Calculation and Verification of the Energy Efficiency Design Index(EEDI) of International Sea-going Ships.

3.3.1.2 The preliminary verification of EEDI speed of ships engaged on domestic voyages is to comply with relevant requirements for preliminary verification in Chapter 3 of the Guidelines for Calculation and Verification of the Energy Efficiency Design Index (EEDI) of Ships Engaged on Domestic Voyages.

3.3.2 Final verification

3.3.2.1 After the coating is applied in dry dock, the hull roughness is to be measured according to 4.4 of the Guidelines. If the roughness deviates more than 5% of the coating surface roughness used in the speed-power curve in preliminary prediction, the speed-power curve of model test is to be corrected first.

3.3.2.2 When the construction of ships is completed, the speed of ships engaged on international voyages is to comply with relevant verification requirements in Chapter 5 of the Guidelines on Calculation and Verification of the Energy Efficiency Design Index(EEDI) of International Sea-going Ships.

3.3.2.3 When the construction of ships is completed, the speed of ships engaged on domestic voyages is to comply with relevant verification requirements in Chapter 4 of the Guidelines for Calculation and Verification of the Energy Efficiency Design Index (EEDI) of Ships Engaged on Domestic Voyages.

3.3.2.4 The speed of the existing ships is to comply with relevant verification requirements of Chapter 3 of the Guidelines on Calculation and Verification of the Attained Energy Efficiency Existing Ship Index (EEXI).

3.3.3 Verification of coating modification

3.3.3.1 For modification of coatings of EEDI ships, the verification of speed is to comply with 6.3 of Chapter 6 of the Guidelines on Calculation and Verification of the Energy Efficiency Design Index(EEDI) of International Sea-going Ships or 5.3 of Chapter 5 of the Guidelines for Calculation and Verification of the Energy Efficiency Design Index (EEDI) of Ships Engaged on Domestic Voyages.

3.3.3.2 For modification of coatings of EEXI ships, the speed may be verified by either of the following ways:

(1) carrying out sea trial according to Appendix 3 of the Guidelines on Calculation and Verification of the Attained Energy Efficiency Existing Ship Index (EEXI);

(2) directly correcting the speed-power curve in the existing sea trial report with the new speed-power curve obtained with the prediction method in 3.2 of this Chapter.

CHAPTER 4 SURVEYS OF COATING APPLICATION

4.1 General requirements

4.1.1 This Chapter applies to the surveys of low-friction coating techniques of newbuildings and surveys of the existing ships for low-friction coating modification, which are to be carried out according to this Chapter, taking into account the requirements of paint manufacturers for coating application.

4.1.2 Before painting, the builder/shipyard is to apply for the survey of coating to ISC field survey unit.

4.1.3 ISC surveyor is to confirm relevant documents of coating, including application procedures, technical specifications and coating arrangement etc..

4.2 Coating application and qualification

4.2.1 The coating application personnel are to be familiar with the key points for coating application and the quality requirements and take up the job after satisfactory completion of the job training by the shipyard or the service representative from the paint manufacturer.

4.2.2 The coating is to be applied under the technical guidance of the service representative from the paint manufacturer.

4.2.3 After the completion of coating application in accordance with the processes and quality standard provided by the service representative from the paint manufacturer, this is to be submitted to ISC surveyor for acceptance.

4.3 Coating application technique and survey requirements

4.3.1 Coating design

4.3.1.1 Documents for coating design are to be provided prior to coating and preliminary preparation, including the following:

(1) means, standards adopted and quality levels for steel surface treatment (including secondary surface treatment);

(2) table of coated area of shell plating and attached structures;

(3) coating supporting system below the waterline, type of paints, colour, number of coats, application sequence, time intervals, dry film thickness and film thickness distribution requirements;

(4) requirements for quality acceptance of rust removal and coating, including the intermediate processes (such as roughening and cleaning, if applicable).

4.3.1.2 The following technical requirements may be added where necessary:

(1) requirements for structural treatment (e.g. welds);

(2) requirements for coating application environment;

(3) repairing processes in case of coating damage and unsatisfactory quality;

(4) paint repair process by removing the keel block (as requested by ship owner).

4.3.2 Coating application specifications

4.3.2.1 Coating application specifications include a general introduction, a table of marine paint types and a table of coating details.The general introduction is to provide a general description of the main requirements for treatment of steel surface and coating of the ship on the basis of construction specifications, which is the basic principle for coating.

4.3.2.2 The table of marine paint types is to summarize the brand, name, colour, physical and chemical characteristics, coating processes, applied areas, ect. For the format of the table, refer to Appendix 2.

4.3.2.3 The table of coating details is to provide a detailed summary of the areas to be coated, paint brand, name, colour, number of coats, and film thickness. An example of the table is given in Appendix 3.

4.3.2.4 The acceptance principle and procedures include the following items:

(1) the department subject to acceptance;

(2) responsibilities or work distribution of the service representative from the paint manufacturer;

(3) roughness testing;

(4) detailed procedures and practice of acceptance.

4.3.3 Inspection requirements

4.3.3.1 Coating is to be applied according to the relevant requirements in the construction specifications and the coating process design document and to be submitted to ISC for acceptance by the quality department after satisfactory inspection.

4.3.4 Coating process record

4.3.4.1 Coating is to be applied according to the processes required by the paint manufacturer and the relevant information and data are to be recorded during coating. Refer to Appendix 4 for items to be recorded and the record format.

4.3.4.2 The recorded documents are to be submitted to the surveyor for review.

4.4 Initial coating surface roughness testing

4.4.1 Upon completion of coating according to the coating application procedures, the shipyard and the manufacturer are to apply for initial coating surface roughness testing as soon as possible.

4.4.2 The measurement of coating surface roughness is needed to be carried out in dry dock or on the slipway/berth and the roughness is to be measured by a measurement company accepted by ISC according to Part 3 of NACE SP0616-2022 Standard for Hull Roughness Measurements on Ship Hulls in Dry Dock and witnessed by a field surveyor. Refer to Appendix 5 for roughness testing record.

4.4.3 A hull roughness testing report, including MHR and AHR, is to be developed and submitted to the surveyor for review and endorsement.

CHAPTER 5 HULL COATING MANAGEMENT PLAN (HCMP)

5.1 General requirements

5.1.1 An HCMP that has been reviewed by ISC is to be kept onboard each ship.

5.1.2 Requirements specified by the existing national and international laws and regulations are at least to be complied with.

5.1.3 The development of HCMP aims to guide the personnel onboard the ship to carry out hull coating monitoring appropriately and effectively and take necessary measures to ensure that the low-friction performance of the coating is well maintained.

5.1.4 The HCMP is to follow a cycle of steps of a circle of planning, implementation, monitoring and inspection, assessment and improvement.

5.1.5 The HCMP is to clearly reflect the features of the ship itself and take a full account of the type of ship, route, voyage, navigation area, ship management personnel and potential situations that may be encountered in practice.

5.1.6 The HCMP is to contain basic elements such as objectives and indicators, resources and responsibilities, document management and operation control.

5.1.7 Management objectives and indicators

5.1.7.1 Indicators are derived from objectives, and are the refinement and break- down of the objective, thus providing specific requirements for achieving the objectives. Indicators are to be quantifiable and indicated by certain parameters.

5.1.8 HCMP resources and responsibilities

5.1.8.1 Necessary resources for the implementation of HCMP, including various aspects such as human resources and material resources.

5.1.8.2 Provision of resources, such as: competent crew members and professional onboard/shore-based management personnel and technical support are required; for monitoring and measurement of data, the ship is required to be equipped with relevant data measurement tools, data storage device, instruments and software systems.

5.1.8.3 The responsibilities, roles and authorities of personnel of various levels are to be clearly defined. The plan is to be written in the working language of the personnel onboard the ship, and if the language is neither English nor Chinese, the translation of at least one of the language is to be included.

5.1.9 HCMP document management and operation control

5.1.9.1 The Plan may be taken as a part of the current management system (e.g.: safety management system) or exists individually.

5.1.9.2 The operation records and monitoring records of the Plan are to be kept for assessment of the management of hull coating and improvement measures.

5.2 Development of HCMP

5.2.1 Low-friction durability factor of hull coating

5.2.1.1 Identification of low-friction durability factor of coating

The identification of low-friction durability factor of coating requires joint efforts by the ship company, the shipyard, the coating supplier and other parties concerned and factors such as the type of ship, type of coating, navigation area, route and voyage are to be considered.

5.2.1.2 Assessment of low-friction durability factor of coating aims to determine the priority and optimal control measures of low-friction durability factor.

5.2.2 Hull coating management measures

5.2.2.1 Determination of hull coating management measures

After the list of low-friction durability factors is established, the management measures are to be determined according to type of ship, route, voyage and navigation area etc.

5.2.2.2 The management measures are to be based on safety premises and meet relevant requirements of relevant regulations and rules.

5.3 Implementation of HCMP

5.3.1 Necessary shore-based resources are to be provided during the implementation of the HCMP.

5.3.2 The HCMP is to describe the requirements for training of onboard personnel engaged in management and operation and take into account the following factors:

(1) senior officers and crew members are familiar with their responsibilities in implementation of the HCMP of the ship;
(2) the master and HCMP operation personnel are familiar with relevant knowledge;
(3) being familiar with the HCMP of the ship;
(4) being familiar with the operation of the HCMP related systems and equipment;
(5) being familiar with the filling of hull coating management records and the log;
(6) being familiar with requirements for safe operation.

5.3.3 Hull coating management report and record

(1) The contents of hull coating management report are to be described, including at least:
  ① designating the crew members responsible for the making and maintaining the hull coating management record;
  ② at least recording the date, location, sea water temperature, salinity and turbidity when the ship is subject to hull coating monitoring or treatment;
  ③ it is to be specified that when the monitoring or treatment of hull coating is not practicable due to weather, sea condition or other reasons, a record is to be made in the hull coating record book;
(2) the format of hull coating management report is to be provided in the Plan;
(3) the record is to be submitted to ISC;
(4) the retention period of the record book is to be specified (to be kept onboard the ship for at least 2 years and later kept by the ship company for at least 3 years).

5.3.4 Records of the data generated during the implementation of the HCMP and records of relevant activities are to be kept.

5.3.5 During the implementation of the HCMP, monitoring is to be carried out according to process control and relevant procedures to ensure the effectiveness of implementation.

5.4 Monitoring of the HCMP

5.4.1 Monitoring of hull coating low friction performance may use but not limited to surface observation method and power analysis method.

5.4.2 The surface observation method includes in-dock observation and underwater observation. Underwater observation may be carried out by means of close-up observation or remotely operated vehicle (ROV) observation.

5.4.3 If the surface observation method is adopted to monitor the hull coating low-friction performance, the monitoring is to be completed as early as possible after the berthing/anchoring of the ship. The monitoring frequency is at least twice every year with a time interval of not less than 3 months.

5.4.4 Configuration of equipment

5.4.4.1 If and ROV is used for observation, the ship or dock is to be provided with an applicable ROV which is to have self-propulsion capability and have a positioning system, a route planning system, a system to clearly record the surface fouling condition of the underwater part of the hull, a data transmission system and a storage system. If relevant storage equipment is provided onboard the ship, the provision of data storage system of ROV itself may be exempted.

5.4.4.2 For image data of the surface fouling condition of the underwater part of the hull recorded by the ROV, a data analysis system is to be installed onboard the ship or this may be achieved by means of shore-based support.

5.4.4.3 If the power analysis method is adopted for monitoring the hull coating low friction performance, an automatic data recording system is to be installed onboard the ship and connected to related sensors to record navigation data of the ship.

5.4.5 Data collection

5.4.5.1 No matter what method is adopted to monitor the hull coating low friction performance, planning is to be made before implementation to clearly define the conditions for implementation of this method and the requirements for data acquisition .

5.4.5.2 The monitoring of hull coating low friction performance is to be carried out according to the time, location and method specified in the HCMP. If the monitoring of the performance is not practicable due to inappropriate loading condition, meteorological condition, flow condition, or sea water quality, it is to be recorded in the record book and temporary adjusting of the implementation plan is to be proposed.

5.4.5.3 If the surface observation method is adopted, the collected image data is at least to cover 70% of the surface area of the underwater hull and the image is to be clear enough to ensure the successful handling of the image data in the next step.

5.4.5.4 If the power analysis method is adopted, the loading condition, meteorological condition, sea condition, delivered power of propeller, and navigation speed are to be recorded in detail to ensure the successful conduct of power analysis.

5.4.6 Calculation and analysis

5.4.6.1 No matter which method is adopted to monitor the hull coating low friction performance, the calculation method and relevant parameters together with the definitions are to be clearly specified in detail.

5.4.6.2 If software is used for analysis of the collected data and releasing the analysis report, the report is to be submitted to ISC for review during the in-service survey and the software is to be approved by ISC.

5.4.7 Corrective measures

5.4.7.1 When the ratio of the sum of the fouling area on the underwater hull observed by means of the surface observation method to the wet surface area of the hull exceeds the corresponding level of the class notation My for hull coating low-friction durability assigned to the ship, the ship operator is to take measures to repair it before the next survey. The repair process and result of repairing are to be recorded in the hull coating record book.

5.4.7.2 When the data obtained by means of the power analysis method prove that the friction resistance on the hull has obviously increased, the ship operator is to formulate and implement measures in a timely manner to ensure that the hull coating returns to a good condition. The process and result of repairing are to be recorded in the hull coating record book.

CHAPTER 6 SURVEY OF SHIPS IN SERVICE

6.1 General requirements

6.1.1 The survey of class notation LFHC (FxMy) is to be carried out in conjunction with periodical survey of the ship.

6.2 Annual survey

6.2.1 Items of annual surveys are as follows:

(1) In general, the visible part of coating of shell plate below the waterline is to be examined;

(2) The hull coating monitoring record book is to be examined to ensure the HCMP is effectively implemented. See Appendix 6 for the format of the record book.

6.3 External inspection of the ship bottom

6.3.1 The hull coating condition is to be examined by means of surface observation and the inspection is to be finished as early as possible after the berthing/anchoring of the ship.

6.3.2 If animal fouling is found, it is to be handled as required and meanwhile the integrity of the coating is to be guaranteed.

6.4 Intermediate survey

6.4.1 Same as the items of annual survey in 6.2.

6.5 Special survey

6.5.1 Same as all items of annual surveys in 6.2.

6.5.2 If type I low-friction coating is applied, the coating thickness is to be measured to determine the performance of the coating.

Appendix 1: Standard Procedure of Performance Prediction Based on Model Tests

This Procedure is based on the inputs from tank model test reports. This Procedure is also applicable to conditions where the inputs come from model-scale CFD report and the CFD calculations are to comply with the requirements of IACS Rec173 and be calibrated based on the tank model test report.

1.1. Calculation of ship speed V_{ref} in case the model tests are conducted with the 3D method

1.1.1 Required Data

In order to estimate $_e$ after roughness modification, the following are required:

(1) Model test report, including EEDI draft full-scale power prediction;

(2) Full-scale propeller open water characteristics;

(3) Relevant model-ship dimensions.

If EEDI draft model test data are not available, this method can be applied on design draft and already known formulas to extrapolate to EEDI draft can be applied (refer to MEPC.350(78) - 2.2.3.4).

1.1.2 Model test standard procedure

The standard model test procedure is to measure R_{TM} , the total resistance in model scale and calculate the model total resistance coefficient C_{TM} using the definition $_{\mathrm{TM}} = {}_{\mathrm{TM}}/(0.5_{\mathrm{M}}^2\ {}_{\mathrm{M}})$, where$_{\mathrm{M}}$M, $_{\mathrm{M}}$, $_{\mathrm{M}}$ are respectively the basin water density (in kg/m³), the model speed (in m/s) and the model wetted surface area (in m²).

Then, $_{\mathrm{FM}}$, the model resistance factor, is calculated as follows:

$$C_{\mathrm{FM}} = \frac{0.075}{(\log_{10}(Re_{\mathrm{M}})-2)^2} \tag{1}$$

Where:

Re_{M} is the Reynolds number defined as $Re_{\mathrm{M}} = V_{\mathrm{M}} \cdot L_{\mathrm{WL}}/(\lambda \cdot \nu_{\mathrm{M}})$;

L_{WL} is the length at the waterline (in m);

λ is the scale ratio, dimensionless;

ν_{M} is the kinematic viscosity coefficient of the basin water (in m^2/s)

C_{WM}, the residual coefficient, is calculated as follows:

$$C_{\mathrm{WM}} = C_{\mathrm{TM}} - (1+k)C_{\mathrm{FM}} \tag{2}$$

Where C_{W} is the wave-making resistance coefficient and C_{WS} is the wave-making resistance coefficient for full-scale ships, and $C_{\mathrm{W}} = C_{\mathrm{WS}} = C_{\mathrm{WM}}$ based on Froude's assumption.

The frictional coefficient in full scale C_{FS} is calculated as follows:

$$C_{\mathrm{FS}} = \frac{0.075}{(\log_{10}(Re_{\mathrm{S}})-2)^2} \tag{3}$$

Where:

Re_{S} is the Reynolds number defined as $Re_{\mathrm{S}} = V_{\mathrm{S}} \cdot L_{\mathrm{WL}}/\nu_{\mathrm{S}}$;

V_{S} is the vessel speed (in m/s);

L_{WL} is the length at the waterline (in m);

ν_{S} is the kinematic viscosity coefficient of the sea water (in m^2/s).

The total resistance coefficient in full scale C_{TS} is calculated as follows:

$$C_{\mathrm{TS}} = \frac{R_{\mathrm{TS}}}{0.5 \cdot \rho_{\mathrm{S}} \cdot {V_{\mathrm{S}}}^2 \cdot S_{\mathrm{S}}} \tag{4}$$

Where:

$_{\mathrm{TS}}$ is the total resistance of the full-scale ship (in N);

$_{\mathrm{S}}$ is the sea water density (in $\mathrm{kg/m^3}$);

$_{\mathrm{s}}$ is the vessel wetted surface area (in $\mathrm{m^2}$).

1.1.3 Tank test according to ITTC 78 - Rev00

In case the 3D model tests have been performed as per ITTC 75-02-03-01.4(1999), then the total resistance coefficient is calculated as follows:

$$C_{\mathrm{TS}} = \frac{S_{\mathrm{S}}+S_{\mathrm{BK}}}{S_{\mathrm{S}}}\left((1+k)\cdot C_{\mathrm{FS}} + \Delta C_{\mathrm{F,1999}}\right) + C_{\mathrm{W}} + C_{\mathrm{AA}} \tag{5}$$

Where:

k is the form factor, dimensionless;

C_{AA} is the air resistance coefficient, dimensionless;

S_{BK} is the bilge keel surface area (in $\mathrm{m^2}$);

$\Delta C_{\mathrm{F,1999}}$ is the dimensionless roughness allowance calculated with the formula below

$$\Delta C_{\mathrm{F,1999}} = \left[105(k_s/L_{\mathrm{WL}})^{\frac{1}{3}} - 0.64\right] \times 10^{-3} \tag{6}$$

Where:

k_s is the hull roughness value, the AHR from hull roughness measurement.

1.1.4 Tank test according to ITTC 78 - Rev01 or later

In case the 3D model tests have been performed as per ITTC 75-02-03-01.4(2008or later), then the total resistance coefficient is calculated as follows:

$$C_{\mathrm{TS}} = \frac{S_{\mathrm{S}}+S_{\mathrm{BK}}}{S_{\mathrm{S}}}\left((1+k)\cdot C_{\mathrm{FS}} + \Delta C_{\mathrm{F,2008}} + C_{\mathrm{A}}\right) + C_{\mathrm{W}} + C_{\mathrm{AA}} \tag{7}$$

Where:

k is the form factor, dimensionless;

C_{AA} is the air resistance coefficient, dimensionless;

S_{BK} is the bilge keel surface area (in $\mathrm{m^2}$);

$\Delta C_{\mathrm{F,2008}}$ is the dimensionless roughness allowance calculated with the formula below:

$$\Delta C_{\mathrm{F,2008}} = 0.044\left[\left(\frac{k_s}{L_{\mathrm{WL}}}\right)^{\frac{1}{3}} - 10\cdot Re_{\mathrm{S}}^{-\frac{1}{3}}\right] + 0.000125 \tag{8}$$

and C_{A}, the resistance conversion correction coefficient, is provided by towing tank facility and normally $C_{\mathrm{A}} = (5.68 - 0.6\log Re) \times 10^{-3}$.

1.1.5 Procedure to calculate effective power $_{\mathrm{E}}$ after roughness modification (Resistance Part)

The new total resistance coefficient $_{\mathrm{TS1}}$ after roughness modification is calculated as follows:

$$C_{\mathrm{TS}_1} = C_{\mathrm{TS}} + \frac{S_{\mathrm{S}}+S_{\mathrm{BK}}}{S_{\mathrm{S}}}\left(\Delta C_{\mathrm{F,i}}(k_{s_1}) - \Delta C_{\mathrm{F,i}}(k_{s_0})\right) \tag{9}$$

Where:

k_{S_0} is the original value of hull roughness given in the original model test report (in m);

k_{S_1} is the AHR measured on the ship after application of low-friction coatings, as mentioned in the measurement report (in m);

$\Delta C_{\mathrm{F,i}}(\mathrm{k}_{\mathrm{S}_0})$ is the dimensionless roughness allowance with formula (8) using $\mathrm{k}_{\mathrm{S}_0}$;

$\Delta C_{\mathrm{F,i}}(\mathrm{k}_{\mathrm{S}_1})$ is the dimensionless roughness allowance with formula (8) using $\mathrm{k}_{\mathrm{S}_1}$.

The total resistance R_{TS_1} is calculated as follows:

$$R_{\mathrm{TS}_1} = C_{\mathrm{TS}_1}\cdot 0.5\rho_{\mathrm{S}}V_{\mathrm{S}}^2 S_{\mathrm{S}} \tag{10}$$

The effective power P_{E_1} is calculated as follows:

$$P_{\mathrm{E}_1} = C_{\mathrm{TS}_1}\cdot 0.5\rho_{\mathrm{S}}V_{\mathrm{S}}^3 S_{\mathrm{S}} \tag{11}$$

1.1.6 Procedure to calculate new delivered power $\mathrm{P_D}$ after roughness modification (Self-Propulsion part) and speed forecast

The propeller will run at a different dimensionless advance coefficient $\mathrm{J} = \mathrm{V_A}/\mathrm{n_S D_S}$, where $\mathrm{V_A}$ is the advance speed in m/s and $V_{\mathrm{A}} = V(1 - w_{\mathrm{TS}})$; w_{TS} is the dimensionless wake fraction; n_{S} is the propeller revolutions in r/s; and D_{S} is the propeller diameter, in m. The new value of J may be obtained from the following formula:

$$K_{\mathrm{T}}/J^2 = \frac{T/\rho_{\mathrm{S}} n_{\mathrm{S}}^2 D_{\mathrm{S}}^4}{V_{\mathrm{A}}^2/n_{\mathrm{S}}^2 D_{\mathrm{S}}^2} = \frac{R_{\mathrm{TS}_1}}{\rho_{\mathrm{S}}(1-t)(1-w_{\mathrm{TS}})^2 V_{\mathrm{S}}^2 D_{\mathrm{S}}^2} = C \Rightarrow K_{\mathrm{T}} = CJ^2 \tag{12}$$

where K_{T} is the dimensionless thrust coefficient.

For the calculation of K_{T}/J^2, the wake fraction at full scale w_{TS} is to be recalculated to adjust for new roughness value.

In case the 3D model tests have been performed as per ITTC 75-02-03-01.4(2008), then the new full-scale wake fraction is to be calculated as follows:

$$w_{\mathrm{TS}_1} = (t + w_{\mathrm{R}}) + (w_{\mathrm{TM}} - t - w_{\mathrm{R}}) \times \frac{(1+k)C_{\mathrm{FS}} + \Delta C_{\mathrm{F,2008}}(k_{s_1})}{(1+k)C_{\mathrm{FM}}} \tag{13}$$

Where w_{TM} is the wake fraction at model scale and w_{R} stands for the effect of rudder on the wake fraction. If there is no estimate for w_{R}, the standard value of $w_{\mathrm{R}} = 0.04$ is to be used. If $w_{\mathrm{TS}_1} > w_{\mathrm{TM}}$, then $w_{\mathrm{TS}_1} = w_{\mathrm{TM}}$.

In case the towing tank facility which performed the original model test did not use the ITTC 75-02-03-01.4(2008), then the new full-scale wake fraction is to be calculated as follows:

$$w_{\mathrm{TS}_1} = w_{\mathrm{TS}_0} \frac{w_{\mathrm{TS}_1,\mathrm{calc}}}{w_{\mathrm{TS}_0,\mathrm{calc}}} \tag{14}$$

Where w_{TS_0} is the full-scale prediction for the wake fraction from the original towing tank tests, $w_{\mathrm{TS}_0,\mathrm{calc}} = (t + w_{\mathrm{R}}) + (w_{\mathrm{TM}} - t - w_{\mathrm{R}}) \times \frac{(1+k)C_{\mathrm{FS}} + \Delta C_{\mathrm{F,2008}}(k_{s_0})}{(1+k)C_{\mathrm{FM}}}$ and $w_{\mathrm{TS}_1,\mathrm{calc}} = (t + w_{\mathrm{R}}) + (w_{\mathrm{TM}} - t - w_{\mathrm{R}}) \times \frac{(1+k)C_{\mathrm{FS}} + \Delta C_{\mathrm{F,2008}}(k_{s_1})}{(1+k)C_{\mathrm{FM}}}$. If $w_{\mathrm{TS}_1} > w_{\mathrm{TM}}$, then $w_{\mathrm{TS}_1} = w_{\mathrm{TM}}$.

Factor C in equation (12) can be easily calculated for every model test speed, using the total resistance value from (10).

To find the new value of J, the following equation must be solved:

$$K_{\mathrm{T}}(J) = CJ^2 \tag{15}$$

To analytically solve (15) with respect to J, the thrust coefficient curve is approximated with 2nd-degree polynomial regression: $K_{\mathrm{T}}(J) \approx \bar{K}_{\mathrm{T}} = aJ^2 + bJ + k$. Thus:

$$aJ^2 + bJ + k = CJ^2 \Rightarrow (a - C)J^2 + bJ + k = 0 \tag{16}$$

The solutions to (16) are:

$$J = \frac{-b \pm \sqrt{\mathrm{Det}}}{2(a-C)}, \mathrm{Det} = b^2 - 4(a - C)\mathrm{k} \tag{17}$$

Rejecting one of the solutions (it turns out to be negative), we now have the new advance coefficient value J_1. For each speed, the new delivered power is calculated as follows:

$$P_{\mathrm{D}_1}(V) = \frac{P_{\mathrm{E}_1}(\mathrm{V})}{\eta_{\mathrm{D}}} = \frac{P_{\mathrm{E}_1}(\mathrm{V})}{\eta_0(\mathrm{V},\mathrm{J}_1)\eta_{\mathrm{H}}(\mathrm{V})\eta_{\mathrm{R}}(\mathrm{V})} \tag{18}$$

Where $\eta_{\mathrm{H}}(V) = (1 - t)/\left(1 - w_{\mathrm{TS}_1}\right)$ and w_{TS_1} is calculated according to (13) or (14); $\eta_{\mathrm{R}}(\mathrm{V})$ is relative rotation efficiency; $\eta_0(\mathrm{V},\mathrm{J}_1)$ is the propeller open-water efficiency.

New brake power prediction is $P_{\mathrm{B}_1} = P_{\mathrm{D}_1}/\eta_{\mathrm{S}}$, η_{S}: shaft efficiency. From the new speed-power prediction curve, $V_{\mathrm{S}} - P_{\mathrm{B}_1}$, substituting $P_{\mathrm{B}_1} = P_{\mathrm{ME}}$, we get the new prediction for the new reference speed $V_{\mathrm{ref},1}$.

1.2 Calculation of V_{ref} in case the model tests are conducted with the 2D Method

1.2.1 Required Data

In order to estimate V_{ref} after roughness modification, the following are required:

(1) Model test report, including EEDI draft full-scale power prediction;
(2) Full-scale propeller open water characteristics;
(3) Relevant model-ship dimensions.

If EEDI draft model test data are not available, this method can be applied on design draft and already known formulas to extrapolate to EEDI draft can be applied (refer to MEPC.350(78) – 2.2.3.4).

1.2.2 Model test standard procedure

The standard model test procedure is to measure R_{TM}, the total resistance in model scale and calculate the model total resistance coefficient C_{TM} using the definition $C_{\mathrm{TM}} = R_{\mathrm{TM}}/(0.5\rho_{\mathrm{M}}V_{\mathrm{M}}^2S_{\mathrm{M}})$, where $\rho_{\mathrm{M}}, V_{\mathrm{M}}, S_{\mathrm{M}}$ are respectively the basin water density (in kg/m^3), the model speed (in m/s) and the model wetted surface area (in m^2).

C_{FM}, the model frictional resistance coefficient, is calculated as follows:

$$C_{\mathrm{FM}} = \frac{0.075}{(\log_{10}(Re_{\mathrm{M}})-2)^2} \tag{19}$$

Where:

Re_{M} is the Reynolds number defined as $Re_{\mathrm{M}} = V_{\mathrm{M}} \cdot L_{\mathrm{WL}}/(\lambda \cdot \nu_{\mathrm{M}})$

Where:

L_{WL} is the length at the waterline (in m);
λ is the scale ratio, dimensionless;
ν_{M} is the kinematic viscosity coefficient of the basin water (in m^2/s).

C_{RM}, the model residual coefficient, is calculated as follows:

$$C_{\mathrm{RM}} = C_{\mathrm{TM}} - C_{\mathrm{FM}} \tag{20}$$

C_{R} is introduced as the residual coefficient, C_{RS} is introduced as the actual ship residual coefficient and $C_{\mathrm{R}} = C_{\mathrm{RS}} = C_{\mathrm{RM}}$ based on Froude's assumption.

The frictional coefficient in full scale C_{FS} is calculated as

$$C_{\mathrm{FS}} = \frac{0.075}{(\log_{10}(Re_{\mathrm{S}})-2)^2} \tag{21}$$

Where:

Re_{S} is the Reynolds number defined as $Re_{\mathrm{S}} = V_{\mathrm{S}} \cdot L_{\mathrm{WL}}/\nu_{\mathrm{S}}$,

Where:

V_{S} is the vessel speed (in m/s);
L_{WL} is the length at the waterline (in m);
ν_{S} is the kinematic viscosity coefficient of the sea water (in m^2/s).

The total resistance coefficient in full scale C_{TS} is defined as:

$$C_{\mathrm{TS}} = \frac{R_{\mathrm{TS}}}{0.5 \cdot \rho_{\mathrm{S}} \cdot {V_{\mathrm{S}}}^2 \cdot S_{\mathrm{s}}} \tag{22}$$

Where:

R_{TS} is the full scale total resistance (in N);
ρ_{S} is the sea water density (in $\mathrm{kg/m^3}$);
S_{s} is the vessel wetted surface area (in m^2).

The total resistance coefficient C_{TS} is calculated with:

$$C_{\mathrm{TS}} = \frac{S_{\mathrm{S}}+S_{\mathrm{BK}}}{S_{\mathrm{S}}}(C_{\mathrm{FS}} + C_{\mathrm{A}}) + C_{\mathrm{R}} + C_{\mathrm{AA}} \tag{23}$$

Where:

C_{A} is the correlation allowance, usually set by the towing tank facility and including uncertainty effects, roughness effects, dimensionless;

C_{AA} is the air resistance coefficient, dimensionless;

S_{BK} is the bilge keel surface area (in m^2).

1.2.3 Procedure to calculate effective power P_{E} (Resistance Part)

According to ITTC75-02-03-01.4 (2008 or later), the roughness effect is considered by the following formula:

$$\Delta C_{\mathrm{F},2008} = 0.044\left[(k_{\mathrm{s}}/L_{\mathrm{WL}})^{\frac{1}{3}} - 10 \cdot Re^{-\frac{1}{3}}\right] + 0.000125 \qquad (24)$$

The new total resistance coefficient C_{TS_1} after roughness modification is calculated with:

$$C_{\mathrm{TS}_1} = C_{\mathrm{TS}} + \frac{S_{\mathrm{S}}+S_{\mathrm{BK}}}{S_{\mathrm{S}}}\left(\Delta C_{\mathrm{F},2008}(k_{s_1}) - \Delta C_{\mathrm{F},2008}(k_{s_0})\right) \qquad (25)$$

Where:

k_{S_0} is the original value of hull roughness given in the model test report. If no value is given in the report, $k_{\mathrm{S}_0} = 150 \cdot 10^{-6}$ m can be used;

k_{S_1} is the AHR measured on the ship after application of low-friction coatings, as mentioned in the measurement report (in m);

$\Delta C_{\mathrm{F},2008}(k_{\mathrm{S}_0})$ is the roughness allowance with formula (24) using k_{S_0}, dimensionless;

$\Delta C_{\mathrm{F},2008}(k_{\mathrm{S}_1})$ is the roughness allowance with formula (24) using k_{S_1}, dimensionless.

The total resistance R_{TS_1} is calculated as follows:

$$R_{\mathrm{TS}_1} = C_{\mathrm{TS}_1} \cdot 0.5\rho_{\mathrm{S}} V_{\mathrm{S}}^2 S_{\mathrm{S}} \qquad (26)$$

Subsequently, the effective power P_{E_1} is calculated as follows:

$$P_{\mathrm{E}_1} = C_{\mathrm{TS}_1} \cdot 0.5\rho_{\mathrm{S}} V_{\mathrm{S}}^3 S_{\mathrm{S}} \qquad (27)$$

1.2.4 Procedure to calculate delivered power P_{D} (Self-Propulsion part) and speed forecast

The propeller will run at a different dimensionless advance coefficient $J = V_{\mathrm{A}}/n_{\mathrm{S}}D_{\mathrm{S}}$, where V_{A} is the advance speed, in m/s, $V_{\mathrm{A}} = V(1 - w_{\mathrm{TS}})$; w_{TS} is the dimensionless wake fraction; n_{S} is the propeller revolutions, in r/s; D_{S} is the propeller diameter, in m. To find the new value of J, we consider the following:

$$K_{\mathrm{T}}/J^2 = \frac{T/\rho_{\mathrm{S}} n_{\mathrm{S}}^2 D_{\mathrm{S}}^4}{V_{\mathrm{A}}^2/n_{\mathrm{S}}^2 D_{\mathrm{S}}^2} = \frac{R_{\mathrm{TS}_1}}{\rho_{\mathrm{S}}(1-t)(1-w_{\mathrm{TS}})^2 V_{\mathrm{S}}^2 D_{\mathrm{S}}^2} = C \Rightarrow K_{\mathrm{T}} = CJ^2 \qquad (28)$$

Where K_{T} is the non-dimensional thrust coefficient.

For the calculation of K_{T}/J^2, the wake fraction at full scale w_{TS} is to be recalculated to adjust for new roughness value.

In case the towing tank facility which performed the original model test used the following formula for the original full-scale wake fraction prediction:

$$w_{\mathrm{TS}_0} = (t + w_{\mathrm{R}}) + (w_{\mathrm{TM}} - t - w_{\mathrm{R}}) \times \frac{C_{\mathrm{FS}}+C_{\mathrm{A}}}{C_{\mathrm{FM}}} \qquad (29)$$

Then, the new full-scale wake fraction is to be calculated as follows:

$$w_{\mathrm{TS}_1} = (t + w_{\mathrm{R}}) + (w_{\mathrm{TM}} - t - w_{\mathrm{R}}) \times \frac{C_{\mathrm{FS}}+C_{\mathrm{A}}+\Delta C_{\mathrm{F},2008}(\mathrm{k}_{\mathrm{S}_1})-\Delta C_{\mathrm{F},2008}(\mathrm{k}_{\mathrm{S}_0})}{C_{\mathrm{FM}}} \qquad (30)$$

Where w_{TM} is the wake fraction at model scale and w_{R} stands for the effect of rudder on the wake fraction. If there is no estimate for w_{R}, the standard value of w_{R} =0.04 is to be used. If $w_{\mathrm{TS}_1} > w_{\mathrm{TM}}$, then $w_{\mathrm{TS}_1} = w_{\mathrm{TM}}$.

In case the towing tank facility which performed the original model test did not use equation (30), then the new full-scale wake fraction is to be calculated as follows:

$$w_{\mathrm{TS}_1} = w_{\mathrm{TS}_0} \frac{w_{\mathrm{TS}_1,\mathrm{calc}}}{w_{\mathrm{TS}_0,\mathrm{calc}}} \qquad (31)$$

Where w_{TS_0} is the full-scale prediction for the wake fraction from the original towing tank tests, and $w_{\mathrm{TS}_0,\mathrm{calc}}$ and $w_{\mathrm{TS}_1,\mathrm{calc}}$ are the values calculated through (29) and (30) respectively. If $w_{\mathrm{TS}_1} > w_{\mathrm{TM}}$, then $w_{\mathrm{TS}_1} = w_{\mathrm{TM}}$.

Factor C in equation (28) can be easily calculated for every model test speed, using the total resistance value in (26).

To find the new value of J, the following equation must be solved:

$$K_{\mathrm{T}}(J) = CJ^2 \tag{32}$$

To analytically solve with respect to J, the thrust coefficient curve is approximated with 2nd-degree polynomial regression: $K_{\mathrm{T}}(J) \approx \bar{K}_T = aJ^2 + bJ + k$. Thus:

$$aJ^2 + bJ + k = CJ^2 \Rightarrow (a - C)J^2 + bJ + k = 0 \tag{33}$$

The solutions to (33) are given by the following:

$$J = \frac{-b \pm \sqrt{\mathrm{Det}}}{2(a-C)}, \mathrm{Det} = b^2 - 4(a - C)k \tag{34}$$

Rejecting one of the solutions (it turns out to be negative), we now have the new advance coefficient value J_1. For each speed value, the new delivered power is calculated as follows:

$$P_{\mathrm{D}_1}(V) = \frac{P_{\mathrm{E}_1}(\mathrm{V})}{\eta_{\mathrm{D}}} = \frac{P_{\mathrm{E}_1}(\mathrm{V})}{\eta_0(\mathrm{V,J_1})\eta_{\mathrm{H}}(\mathrm{V})\eta_{\mathrm{R}}(\mathrm{V})} \tag{35}$$

Where hull efficiency $\eta_{\mathrm{H}}(V) = (1 - t)/(1 - w_{\mathrm{TS}_1})$ and w_{TS_1} is calculated according to (30) or (31); $\eta_{\mathrm{R}}(\mathrm{V})$ is relative rotation efficiency; $\eta_0(\mathrm{V}, \mathrm{J}_1)$ is the propeller open-water efficiency.

New brake power prediction is $P_{\mathrm{B}_1} = P_{\mathrm{D}_1}/\eta_{\mathrm{S}}$, η_{S}: shaft efficiency. From the new speed-power prediction curve, $V_{\mathrm{S}} - P_{\mathrm{B}_1}$, substituting $P_{\mathrm{B}_1} = P_{\mathrm{ME}}$, we get the new prediction for the new reference speed $V_{\mathrm{ref},1}$.

Appendix 2: Table of marine paint types

Serial No.	Paint type		Color (Color card No.)	Film thickness		Density kg/m^3	Mixture ratio (volume ratio)	Mixture application period h	Theoretical coverage kg/m^3	Dry time h	Coating interval h/20℃		Dilution rate	Thinner	Applied area
	Brand	Name		Dry film	Wet film						Shortest	Longest			
1															
2															
3															
4															
5															

Appendix 3: Table of coating details

Serial No.	Coating location	Primer			Topcoat				Remarks
		Paint type	Dry film thickness	Number of coats	Paint type	Dry film thickness	Number of coats	Color	
	I. Hull shell plating								
1	Hull bottom (including sea chest, bilge keel)								
2	Waterline								

Appendix 4: Record of coating process

The following is an example table of sectional painting records. This can also be used as a reference for erection painting, painting repair and overall painting.

Location:		Date:		Serial No.:	
Ship name/No.:			Block No.:		
Construction company:			Quality inspector:		
No./name of the process (standard) used:					
Parameters and standards for painting confirmation process:					

Operator/ serial No. of qualification certificate	Name/serial No.	Name/serial No.	Name/serial No.	Name/serial No.

Name/serial No./validity of the equipment used:	
Name/serial No./validity of the inspection equipment:	

Paint manufacturer						Segment area in m^2					
Paint degree		First		Second		Third		Fourth		Fifth	
Paint name											
Product marking/No.:										6	
Paint batch No. Base stock/curing agent											
Measurement time											
Temperature of steel plate	℃										
Air temperature	℃										
Relative humidity	%										
Dew point	℃										
Oil pollution		□ Yes □ No		□ Yes □ No		□ Yes □ No		□ Yes □ No		□ Yes □ No	
Dry film thickness requirement		Measured quantity	Percent	Measured quantity	Percent	Measured quantity	Percent	Measured quantity	Percent	Measured quantity	Percent
＜90% NDFT											
90%NDFT~NDFT											

≥NDFT										
Total:										
Remark: (Measurement data table as attached)										

Condition	Personnel qualification	Equipment and tools	Coating material	Process file	Ambient condition
Confirmation					
Checked by:			Date:		

Appendix 5: Record of roughness inspection

1	Ship name	
2	Operator	
3	Location and country of dry dock	
4	Dry dock time	
5	Date of inspection	
6	Form of inspection (dry dock/slipway/building berth)	
7	Inspection personnel	
8	Inspection instrument/meter No.	
9	Measurement institution	
10	Latest calibration date of instrument/equipment	
11	Inspection report	See the attachment.

Appendix 6: Monitoring record of hull coating

1	Ship name		
2	IMO No.		
3	Flag		
4	Date of delivery		
5	Last date of coating		
6	Type and model of paints		
7	Route of last voyage		
8	Speed of last voyage		
9	Arrival time of ship at port/anchorage		
10	Surface coating monitoring method		
11	Start time of monitoring		
12	Completion time of monitoring		
13	Monitoring location		
14	Monitoring personnel		
15	Load draught		
16	Weather and sea condition of monitoring location	Seawater temperature	
		Salinity and turbidity	
		Wind scale	
		Wave height	
		Current rate	
17	Reasons for failure in operation/record (if necessary)		
18	Monitoring report		See the attachment.
19	Suggestion for coating management		
20	Implementation of suggestion		
21	Recorded by		
22	Date of record		

Signature of the recording personnel:

Appendix 7: Sample of numerical calculation report

1 Introduction

This report contains the numerical calculation results of the EEDI reference speed (Vref) for XXX (ship name). The method and procedures used in this report comply with ITTC's latest requirements for numerical calculation and Guidelines for EEDI Calculation and Verification of Ships Engaged in Domestic Voyages.

The numerical calculation modelling and solving methods used in this report have been applied to the parent ship YYY (ship name) of XXX (ship name). The calibration coefficient of this method is 1.02 after comparing the calculation results of parent ship YYY (ship name) with model test results. The lines and parameter comparison between XXX (ship name) and YYY (ship name), the numerical calculation report of YYY (ship name), the comparison and analysis between numerical calculation results and model test results of YYY (ship name) are listed in the attachment.

2 Qualification

During the past five years, ZZZ (company name) has carried out multiple numerical calculation studies according to ITTC 7.5-03-01-02, covering aspects such as ship resistance and propulsion performance. An example of the project is as follows:

Serial No.	Year	Brief description of the project	Ship type for calculation	Ship main dimension	Gap with the target value*（%）
1					
2					
3					
4					
5					
…					
…					

* After the comparison of curve results, take the average value of the differences in the comparison results of multiple points on the curve.

3 Supporting documents

The following plans and information are used for this numerical calculation and the texts of these documents are attached.

Document No.	Document name	Description
1	YYY Model Test Report	
2	XXX General Arrangement Plan	
3	XXX Propeller Plan	
…		

4 Introduction to CFD software

This numerical calculation is completed using Cadence Fidelity Marine V10. Fidelity Marine encompasses a pre-processing module for the creation of all hexahedral unstructured meshes, an incompressible fluid viscosity solver, and a powerful post-processing module. It is a professional hydrodynamic simulation tool specifically developed by Cadence for the marine engineering field, featuring the most advanced application technologies in the marine industry. It can simulate the single-phase and multi-phase viscous flow fields around any complex ships and marine structures. It can simulate the performance of deep-sea vessels as well as inland shallow-water vessels. It can also simulate complex scenarios such as the effects of mooring systems and the encounter of two ships. Moreover, it has the functions of specialized and modularized high-precision prediction for resistance, seakeeping, maneuvering, and propellers, as well as multi-physics field simulation capabilities for ship-propeller coupling, self-propulsion prediction, cavitation, and fluid-structure interaction in complex flow fields.

5 Ship and propeller information

Basic information of ship:

Ship name	
IMO No.	
Ship type	
Rated power of main engine, in kW	
Rated speed of main engine, in rpm	
Deadweight tonnage, in t	
Light weight, in t	
Design draft, in m	
EEDI draft, in m	
Length between perpendiculars, in m	
Molded breadth, in m	
Molded depth, in m	

Basic information of propeller:

Diameter, in m	
No. of blade	
Direction of rotation	
Expanded area ratio	
Diameter of propeller hub, in m	
Chord length at 0.7R, in m	
Maximum thickness at 0.7R, in m	
Pitch ratio at 0.7R	

6 Explanations for CFD modelling

6.1 Geometric introduction to the model

Ship modelling information:

Item	Calculation modelling
Scale ratio	
Overall length, in m	
Length between perpendiculars, in m	
Molded breadth, in m	
Molded depth, in m	
Design draft, in m	

Displacement volume corresponding to design draft, in m^3	
Wet surface area corresponding to design draft, in m^2	
EEDI draft, in m	
Displacement volume corresponding to EEDI draft, in m^3	
Wet surface area corresponding to EEDI draft, in m^2	
Lengthwise position of buoyant centre, in m	
Vertical position of buoyant centre, in m	
Vertical position of center of gravity, in m	

Propeller modelling information:

Item	Calculation modelling
Scale ratio	
Diameter, in m	
No. of blade	
Direction of rotation	
Expanded area ratio	
Diameter of propeller hub, in m	
Chord length at 0.7R, in m	
Maximum thickness at 0.7R, in m	
Pitch ratio at 0.7R	

See Figure 6.1-1 for the overall geometric model of the numerical modelling.

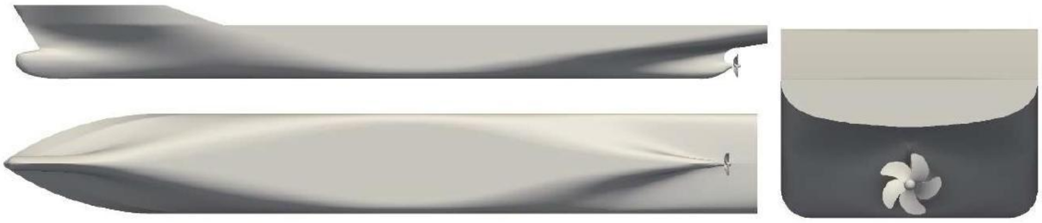


Figure 6.1-1 The overall geometric model of the ship

The appendages of this model cover XXX, XXX, XX and XXX.

See Figures 6.1-2 and 6.1-3 for the detailed geometric modeling of ship appendages and propeller.

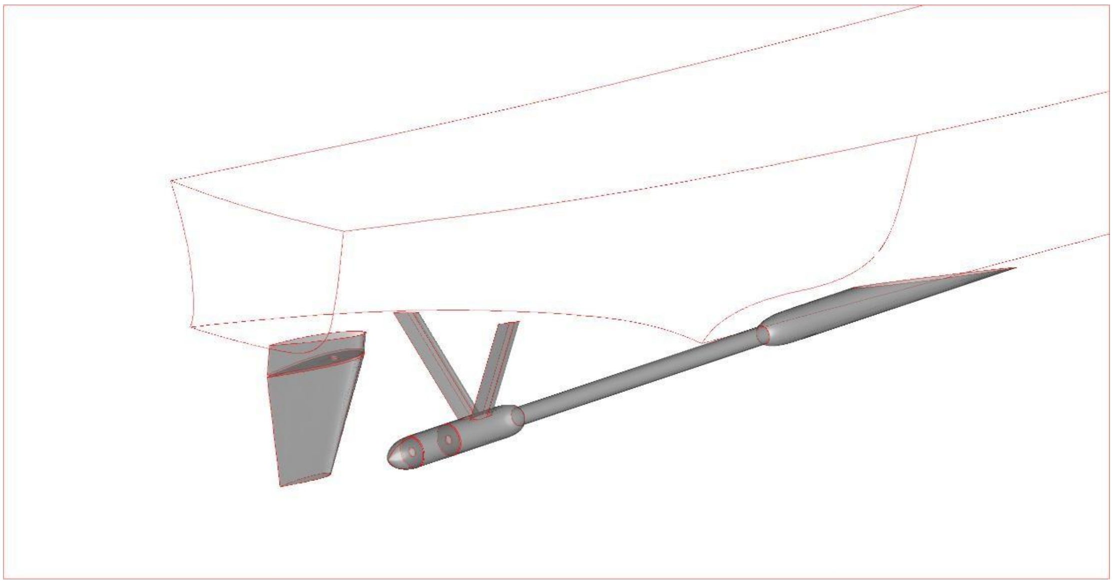


Figure 6.1-2 Geometric modeling of ship appendages

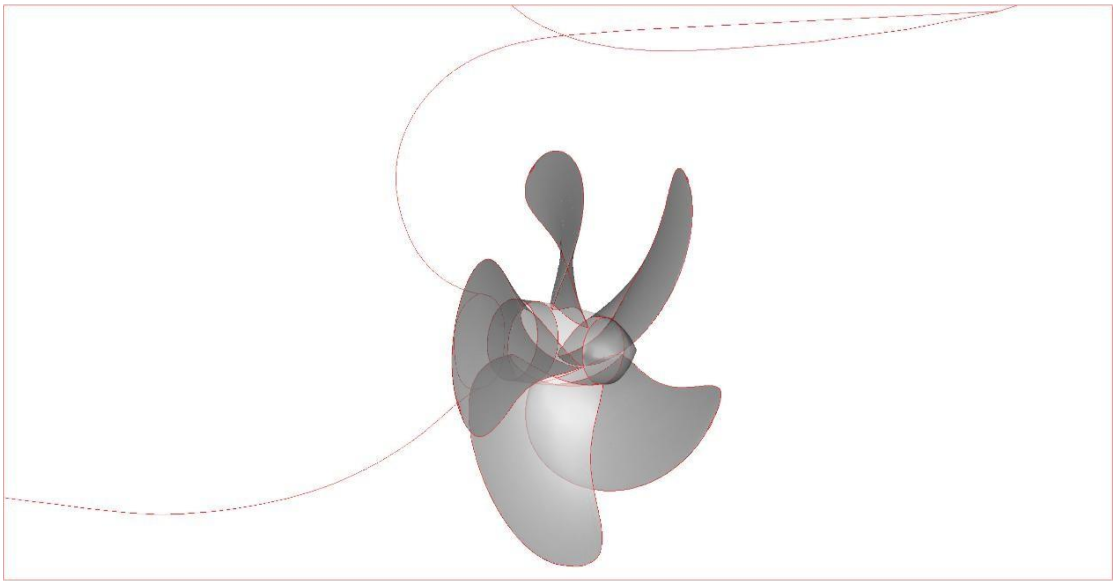


Figure 6.1-3 Geometric modeling of propeller

6.2 Description of meshing

(The meshing strategy needs to be described in detail, including descriptions of the mesh regions, sizes and types (boundary layers, element sizes, etc.). If the mesh sizes are not the same, different refined regions and each direction (x, y, z) should be explained. Different views of different refined regions also need to be provided, along with schematic diagrams.)

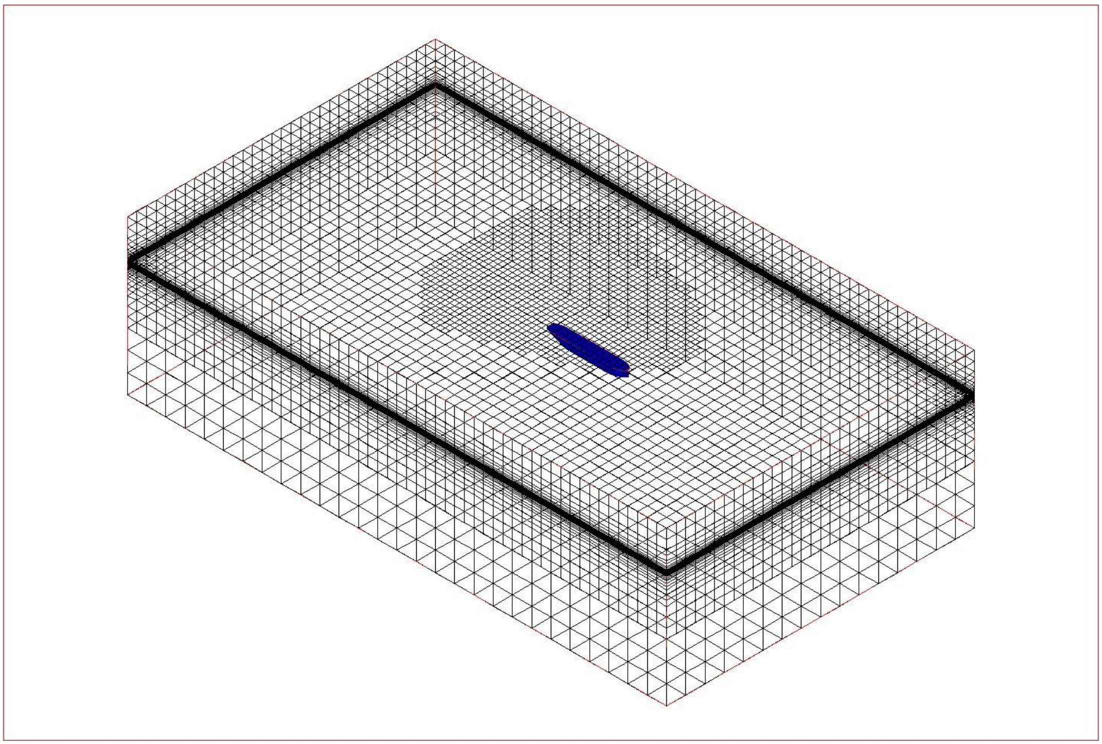


Figure 6.2-1 Division of computational domains

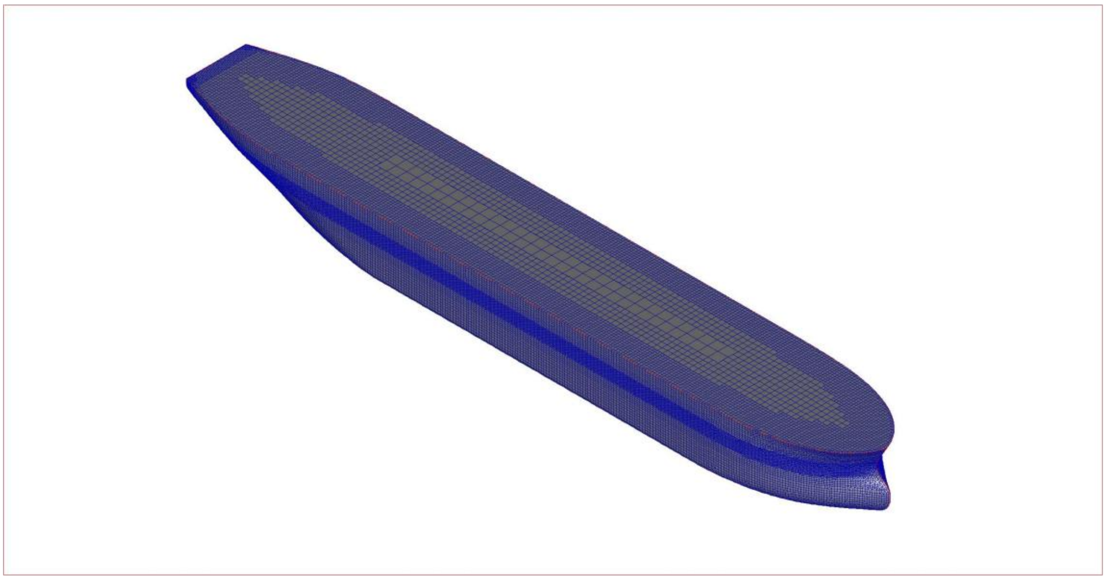


Figure 6.2-2 Three-view drawing of meshing

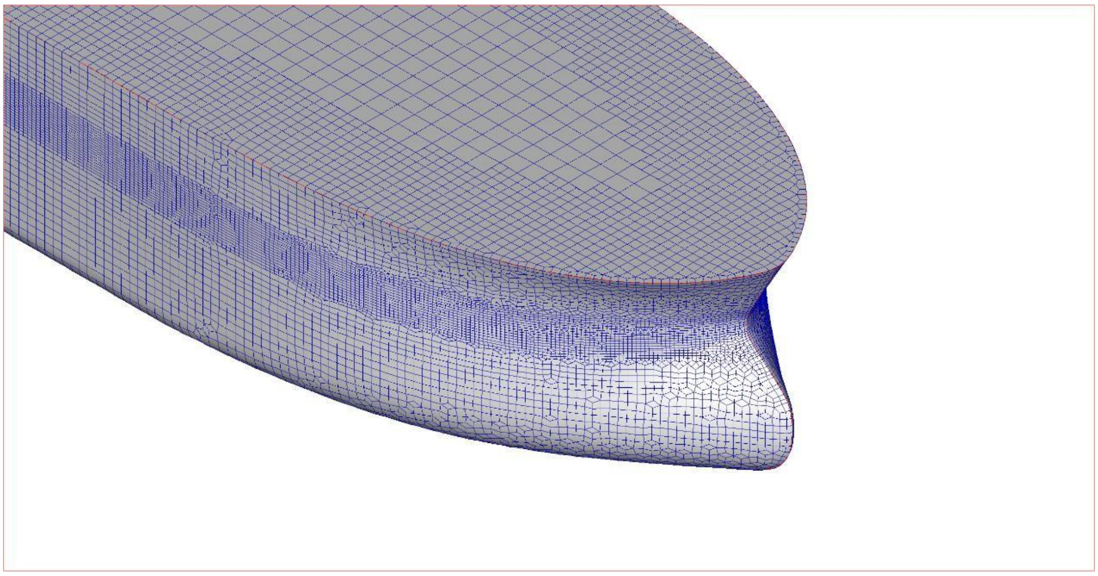


Figure 6.2-3 Meshing at the bow

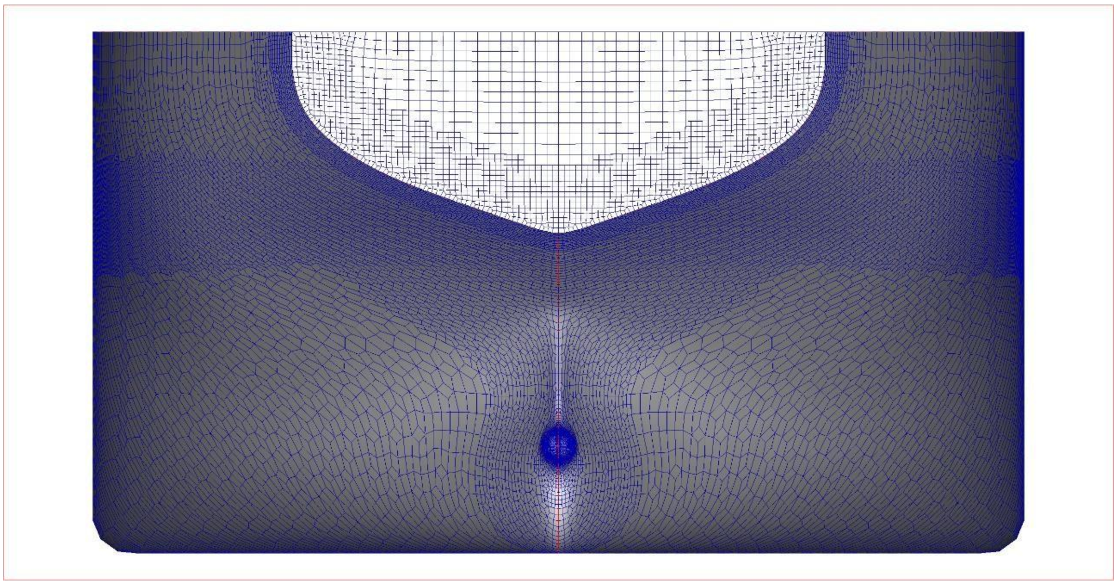
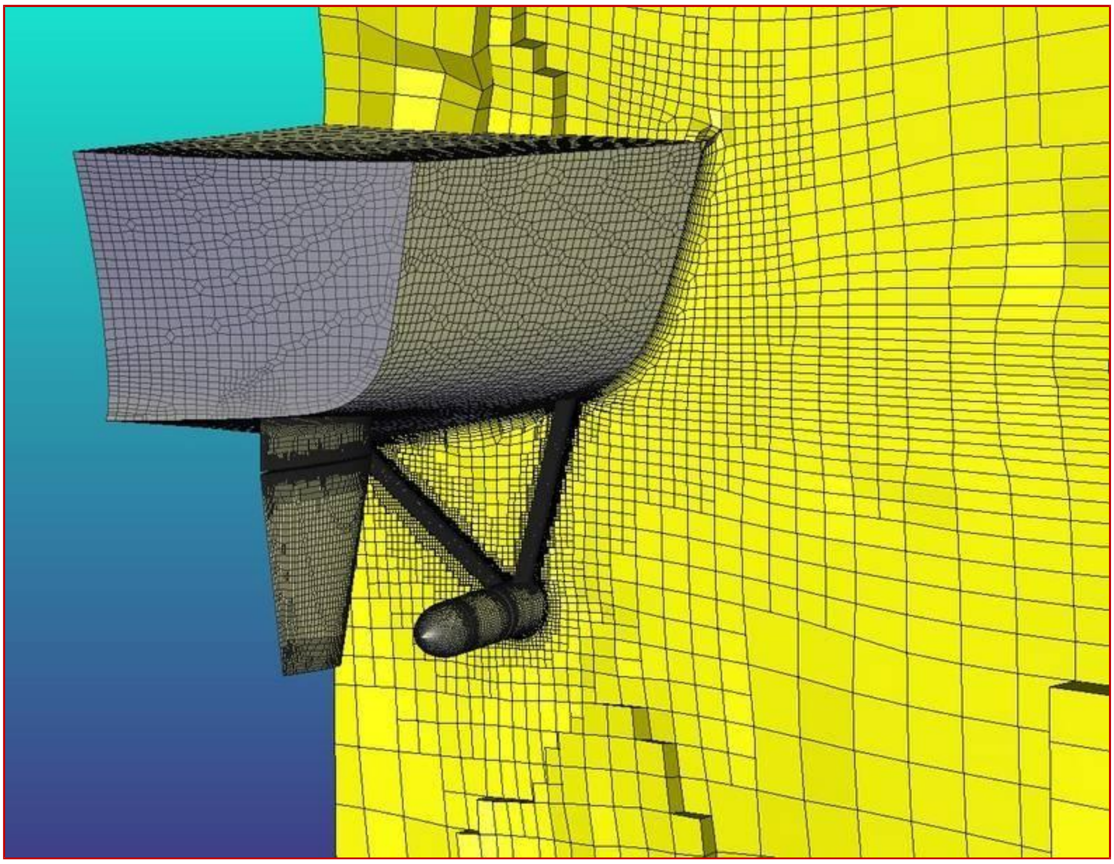
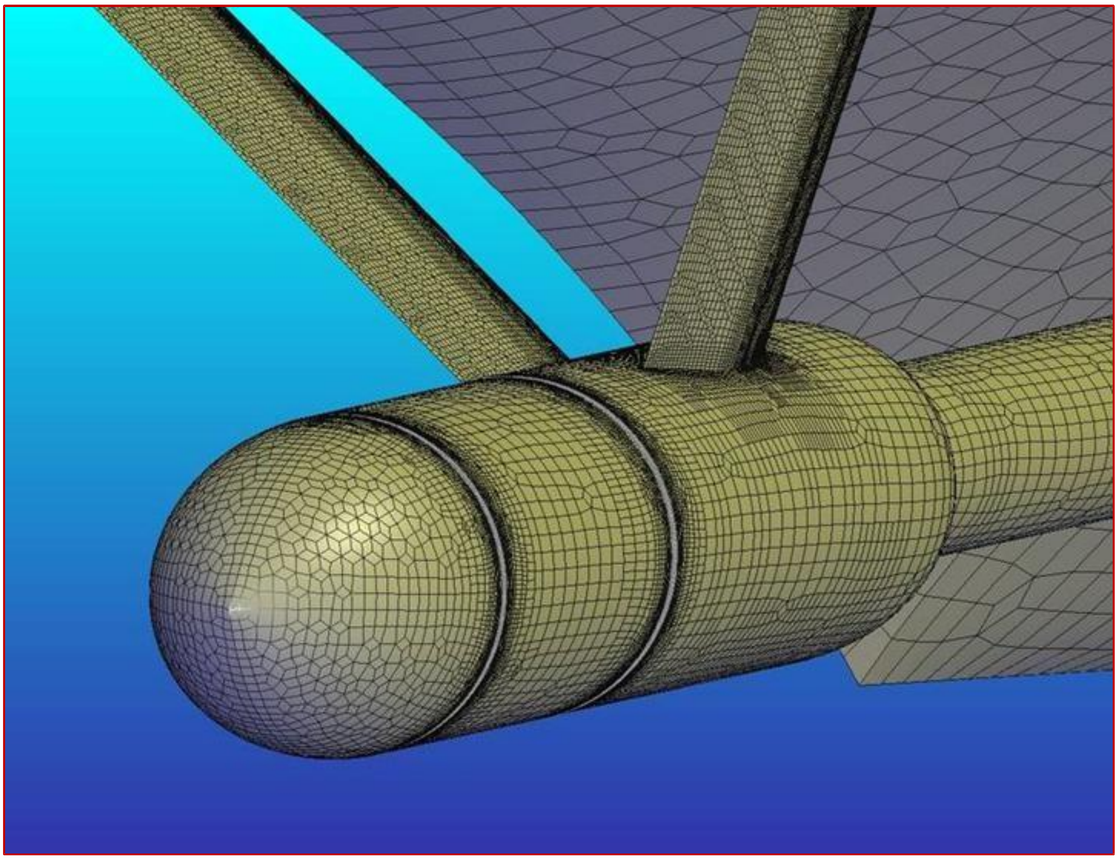


Figure 6.2-4 Meshing at the stern





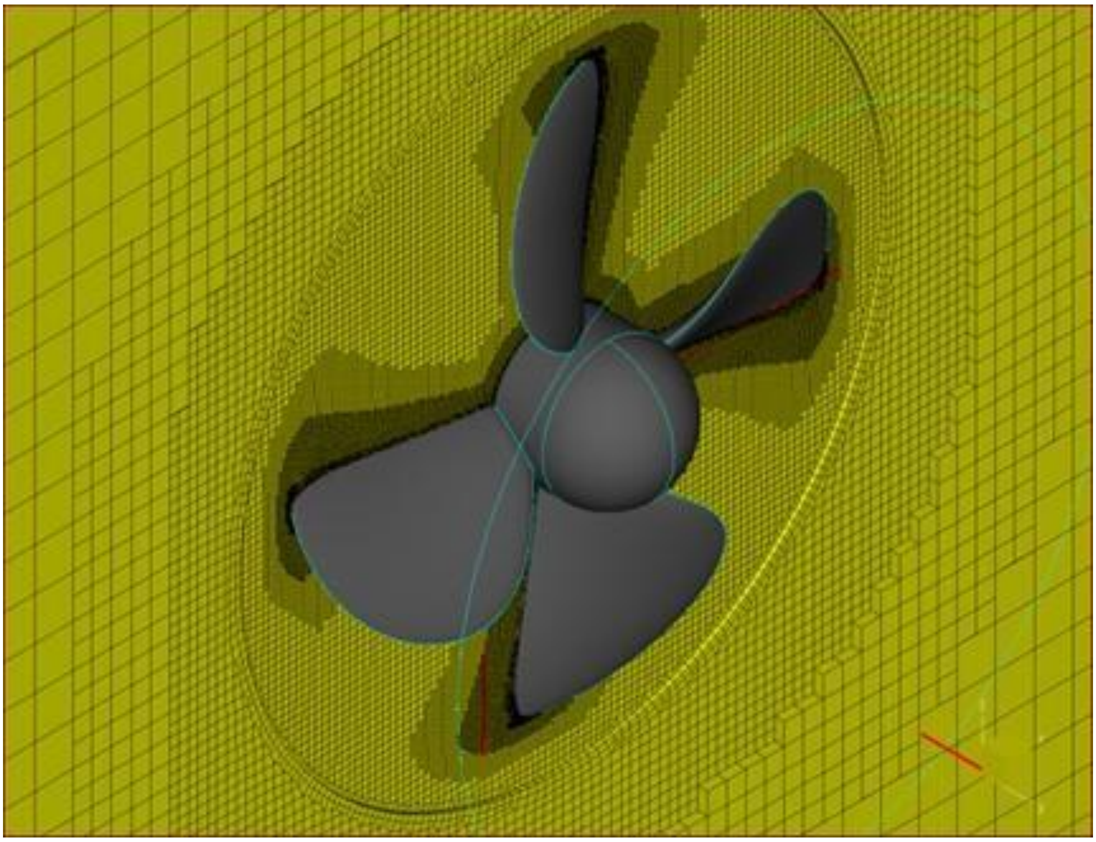


Figure 6.2-5 Meshing at the ship appendage

6.3 Verification of mesh convergence

The meshing strategy of this model is the same as that for the parent ship. For the details of the mesh convergence verification of the parent ship, please refer to the attachment.

7 Setting of numerical calculation

7.1 Governing equations

7.2 Simulation type

7.3 Turbulence model (including reason for selection)

7.4 Numerical solving method (including iteration stopping criteria)

7.5 Boundary conditions (including description of computational domain division)

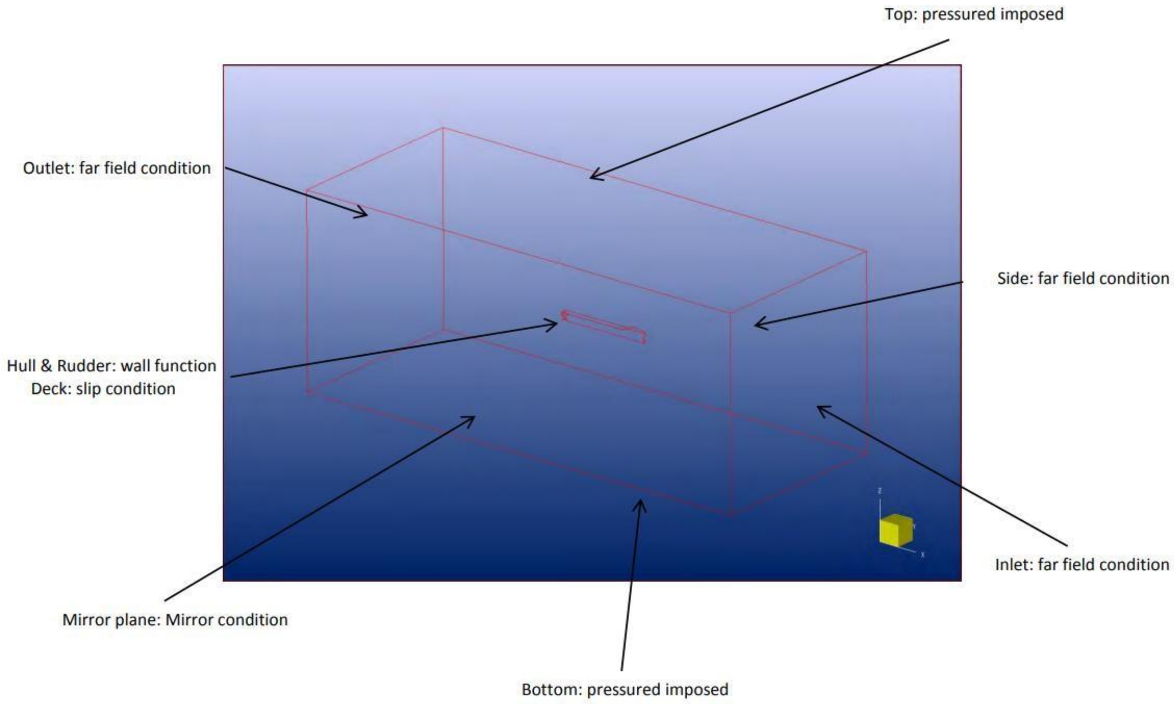


Figure 7.5 Setting of calculation boundary conditions

7.6 Setting of coordinate system and degree of freedom of the model

7.7 Description of propeller modelling

7.8 Setting of initial conditions (including convergence criteria)

8 Post-processing and result analysis

8.1 Post-processing

(Description of the post-processing procedures used (such as average values, final values, etc.), as well as the description of the method for finding the results of the self-propulsion point.)

8.2 Calculation results

8.2.1 Statistics of calculation results

The numerical calculation results of each parameter at the model scale is listed in the table below.

Parameter	Condition 1	Condition 2	Condition 3	……	Condition 10
Total resistance, in N					
Viscous resistance, in N					
Pressure resistance, in N					
Thrust deduction, in t					
Wake fraction, in w					
Propeller thrust, in N					
Propeller torque, in N*m					
Propeller efficiency					

Parameter	Condition 1	Condition 2	Condition 3	……	Condition 10
Related rotation rate, in r/s					
Delivered power of main engine, in W					

8.2.2 Residual convergence diagram

(Residual convergence diagram of ship static resistance, self-propulsion resistance, propeller thrust, and propeller torque.)

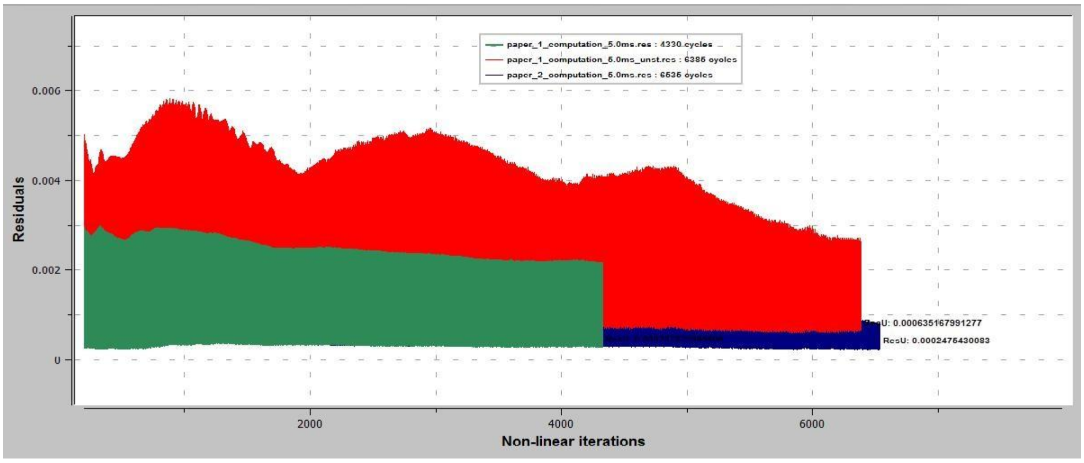


Figure 8.2.2 Numerical residual convergence diagram (schematic of resistance)

8.2.3 Result convergence diagram

(Result convergence diagrams of ship static resistance, self-propulsion resistance, propeller thrust and propeller torque.)

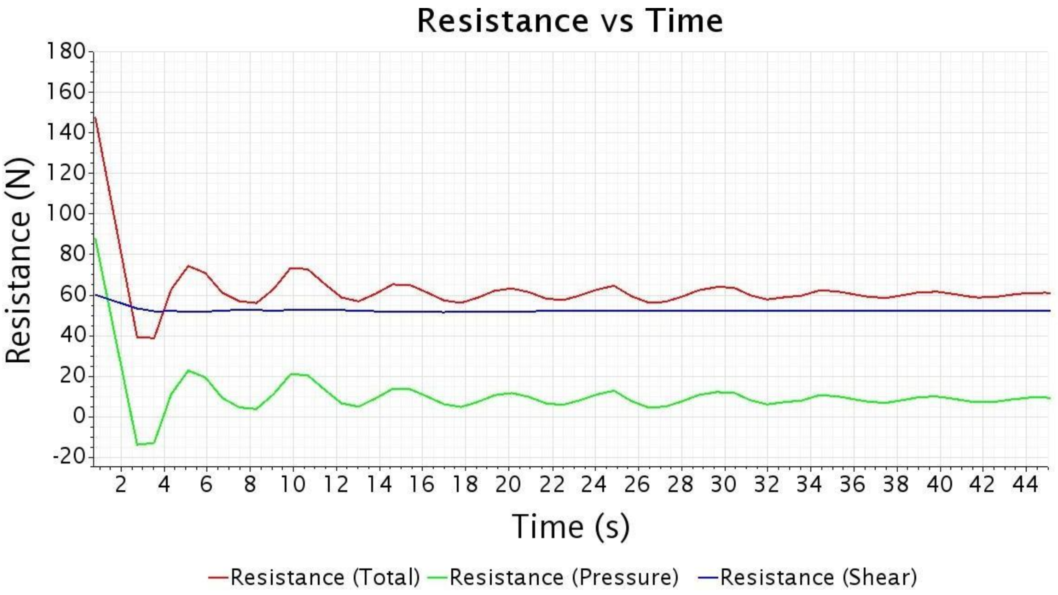


Figure 8.2.3 Result convergence diagram (schematic of resistance)

8.2.4 Wave height, pressure and flow field diagrams

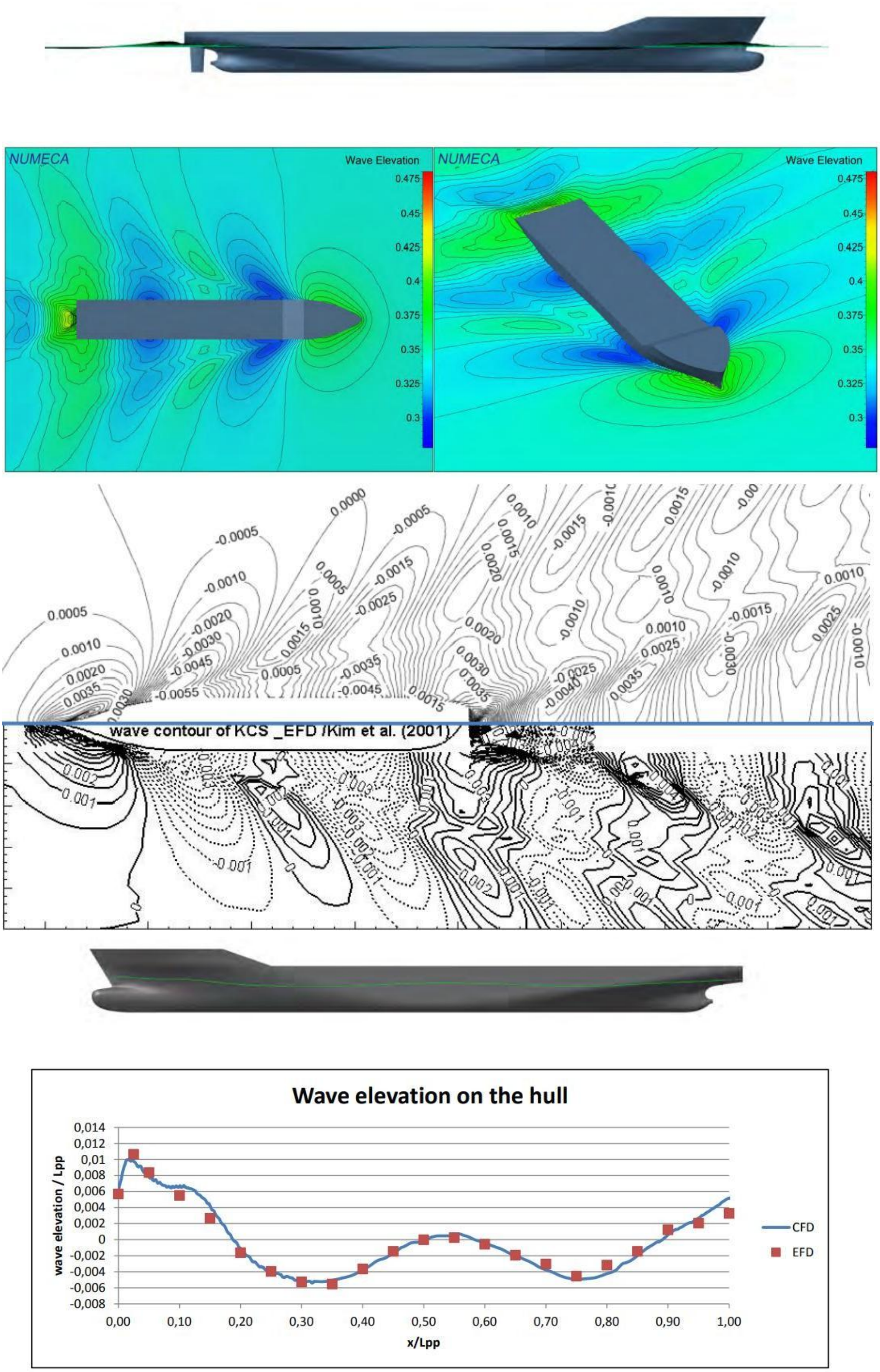
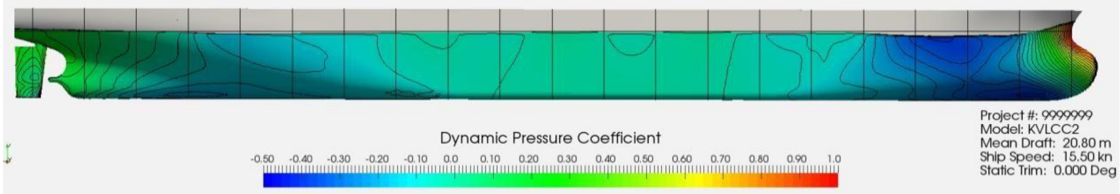


Figure 8.2.4-1 Free surface wave pattern diagram.



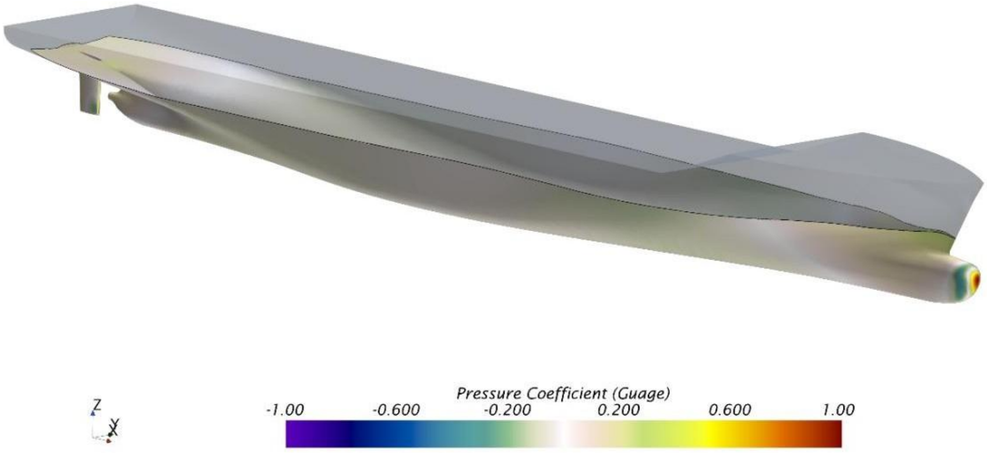


Figure 8.2.4-2 Hull pressure distribution diagram

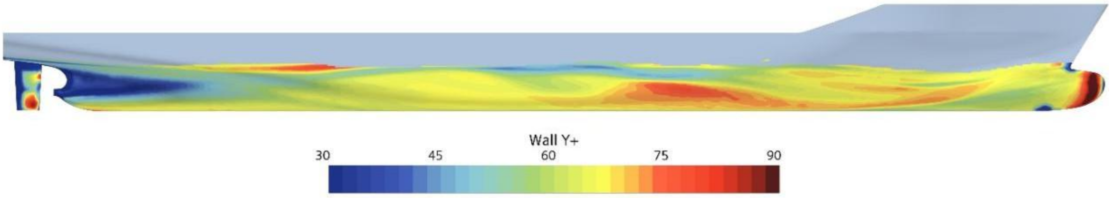


Figure 8.2.4-3 Y+ value distribution diagram

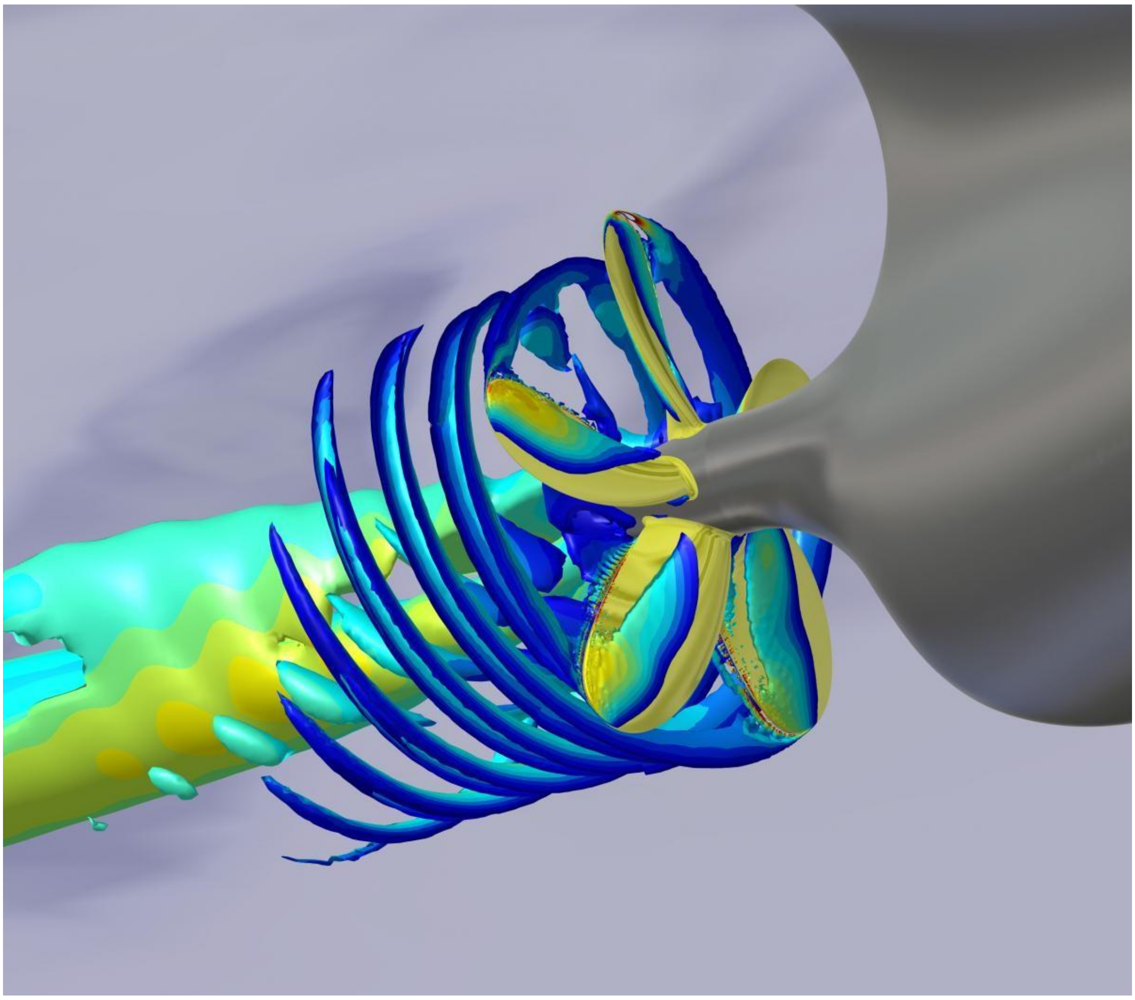


Figure 8.2.4-4 Flow field distribution at the propeller

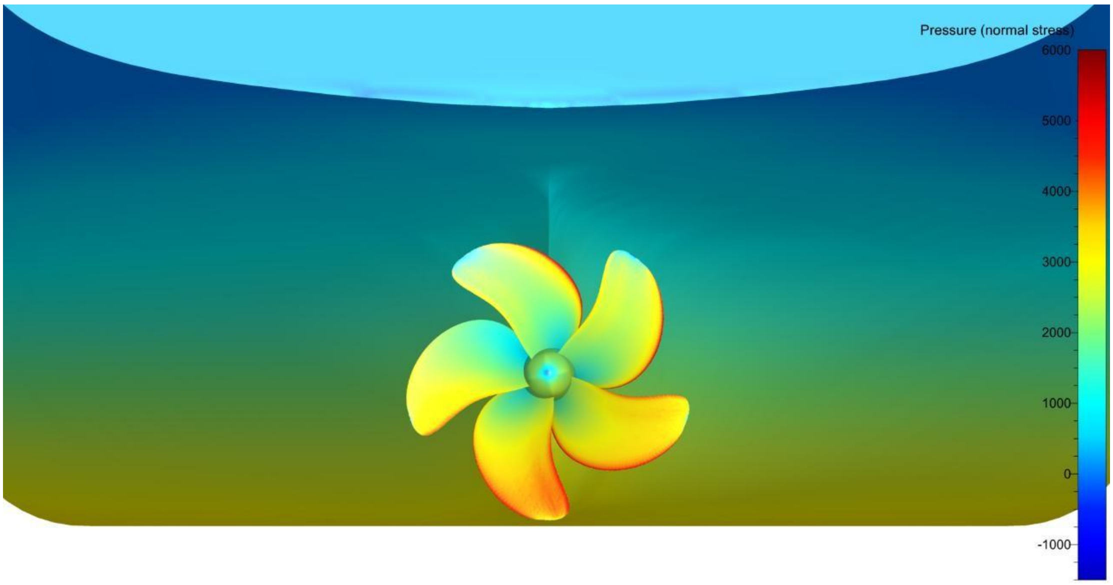


Figure 8.2.4-5 Propeller pressure distribution diagram

8.3 Result conversion

8.3.1 Conversion method for model - full-scale ship

(Explanation on the converting the calculation results at the model scale to those at the full-scale ship.)

8.3.2 Result summary

The calculation results of each parameter at the full-scale ship are listed in the table below.

Parameter	Condition 1	Condition 2	Condition 3	……	Condition 10
Total resistance, in N					
Viscous resistance, in N					
Pressure resistance, in N					
Thrust deduction, in t					
Wake fraction, in w					
Propeller thrust, in N					
Propeller torque, in N*m					
Propeller efficiency					
Related rotation rate, in r/s					
Delivered power of main engine, in W					

9 Explanation of verification and evaluation of the numerical calculation method

(A detailed description of the numerical method adopted to demonstrate the rationality of the numerical calculation results.)

Annex 1 The comparison of lines and parameters between XXX (ship name) and YYY (ship name)

Annex 2 Numerical calculation report of YYY (ship name)

Annex 3 The comparison and analysis between numerical calculation results and model test results of YYY (ship name) (including the acquisition of calibration coefficient)

Annex 4 (Text of supporting document -1)

Annex 5 (Text of supporting document -2)

……

Annex X (Text of supporting document -X)