GUIDANCE NOTES
GD20-2020

GUIDELINES FOR SURVEYS OF AIR LUBRICATION SYSTEM FOR DRAG REDUCTION OF SHIPS

2020

Effective from 1 July 2020

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CHAPTER 1 GENERAL

1.1 General provisions

1.1.1 The Guidelines apply to sea-going ships installed with air lubrication system for drag reduction.

1.1.2 The Guidelines provide the technical requirements for the system design, air supply devices, piping systems, air layer/ bubble generators, air escape protector, power supply and electrical systems, and control and monitoring systems, clarified requirements for surveys of relevant equipment and proposed methods of calculation and requirements for verification of EEDI of ships installed with air lubrication system for drag reduction.

1.1.3 The provisions of the Guidelines apply to the type of the currently applied air lubrication system for drag reduction. Considering that the technology is still under development, other types of systems, with their calculation methods, evaluation standards, survey and test methods, may be accepted as alternatives and equivalent methods with the consent of ISC provided that related test and theoretical basis, service experience or effective recognized standards are provided.

1.1.4 In addition to the requirements of the Guidelines, sea-going ships installed with the air lubrication system for drag reduction specified in the Guidelines are to comply with corresponding statutory requirements together with the applicable requirements of ISC Rules for Classification of Sea-Going Steel Ships and Rules for Materials and Welding based on the characteristics and navigation areas of ships.

1.2 Definitions

1.2.1 For the purpose of the Guidelines:

(1) Air lubrication technology: a novel energy saving technology to reduce the friction resistance of ships and lower the fuel consumption by filling appropriate amount of air to the bottom of hull so as to form and maintain a mixture layer of air and liquid or a layer of air taking advantage of the difference of air and water in density and viscosity. According to the resistance reduction mechanism and ways of implementation, the technologies are classified as air layer drag reduction, microbubble drag reduction and air cavity drag reduction.

(2) Air layer drag reduction technology: a novel energy saving technology of dispersing appropriate amount of air to the bottom of hull by air layer reduction device to form and maintain a thin layer of air that separates the hull from water and decrease the wet surface area of the bottom and reduce the resistance, which may also be called air film drag reduction.

(3) Microbubble drag reduction technology: a novel energy saving technology of generating microbubbles with micro-sized diameter in the vicinity of the outer surface of the bottom by bubble generator to form a thin air-liquid two-phase flow, reduce the density and viscosity of the flow in the vicinity of outer surface of bottom and change the internal flow within turbulent boundary to reduce the resistance of ships.

(4) Air cavity drag reduction: a novel energy saving technology of building a deep recess (air cavity) on the hull to keep the air within the air cavity by means of air cavity resistance reduction device so as to decrease the wet area of ships and reduce the resistance of ships.

(5) Air supply device: an air supply unit to provide the air lubrication systems with air of a certain pressure and flow volume.

(6) Air supply piping system: an air transportation piping system which transports the air supplied

by air supply device to the air layer/bubble generator. Compressed air piping system or ventilation piping system may be adopted as needed.

(7) Air layer/bubble generator: a device capable of generating air layer/ bubble covering the bottom of the hull or a device capable of generating air to fill the air cavity at the bottom.

(8) Air escape protector: a device installed on the bottom of the hull to prevent air escape and maintain the resistance reduction effect.

(9) Monitoring and control system: a sub-system of the air lubrication system which is composed of monitoring and control instruments, having monitoring and control functions to monitor each performance parameter of the ship and air lubrication and drag reduction system, control key components and safeguard the effective operation of the whole system.

1.3 Class notations

1.3.1 If the air lubrication technology for drag reduction is applied and the requirements of Chapters 1 and 2 of the Guidelines are complied with, the class notation ALDR (air lubrication for drag reduction) may be assigned upon request.

1.3.2 For ships to which 2.3.2 of ISC Rules for Green Eco-Ships applies, if air lubrication system for drag reduction are installed, the calculation and verification of the energy saving effect of air lubrication system for drag reduction may be carried out according to the requirements of Chapter 3 of the Guidelines and the class notation CD_x may be assigned after the calculation result is included in the Attained EEDI of the ship.

1.3.3 For ships to which 2.3.2 of ISC Rules for Green Eco-Ships does not apply, the class notation ALDR may be assigned separately.

1.4 Plans and documents

1.4.1 The following plans and documents are to be submitted for approval, and repeated submission is not needed if already included in those required to be submitted by the ship:

(1) arrangement of air lubrication system for drag reduction;

(2) structural plan of air layer/ bubble generator;

(3) structural plan of air escape protector (if any);

(4) arrangement of piping system;

(5) arrangement of air supply device;

(6) power load estimation of air lubrication system for drag reduction;

(7) power system diagram of air lubrication system for drag reduction, including:

a. circuits of ventilation system;

b. cable type, sectional area of conductor, current rating of electrical system;

if dedicated electric motor is adopted:

c. circuits of the motor and motor protection;

d. shutoff device of the motor controller.

1.4.2 For retrofitted ships, the following plans and documents are to be supplemented for approval:

(1) stability manual, damage stability calculations and loading instrument (if applicable);

(2) longitudinal strength calculations of air lubrication system for drag reduction area(if applicable);

(3) in-water survey mark and arrangement plan or manual (applicable to the retrofitted ships

assigned with class notation “In-Water Survey”).

1.4.3 The following plans and documents are to be submitted for information:

(1) system specifications, at least to include general descriptions of the system and descriptions of functions of each main component, system principles, system control function and external interfaces;

(2) system and equipment specifications;

(3) local structural strength direct calculations of air lubrication and drag reduction system area(if applicable);

(4) resistance estimations of air supply piping;

(5) power estimations of air supply device;

(6) power test report of air supply device (if any);

(7) EEDI calculations and technical files (if applicable);

(8) estimation of the change in lightship weight and its center of gravity and assessment of stability effect (applicable to retrofitted ships).

1.5 Equipment

1.5.1 Equipment of an air lubrication system for drag reduction are to operate within the design working conditions and their performances are to meet the service requirements of the design conditions of the system.

1.5.2 The power unit of an air lubrication system for drag reduction is to meet the applicable requirements of Chapter 2, PART FOUR of ISC Rules for Classification of Sea-Going Steel Ships.

1.5.3 The frequency converter of an air lubrication system for drag reduction is to meet the applicable requirements of Chapter 3, PART FOUR of ISC Rules for Classification of Sea-Going Steel Ships.

1.5.4 The control system of an air lubrication system for drag reduction is to meet the applicable requirements of Chapter 3, PART FOUR of ISC Rules for Classification of Sea-Going Steel Ships.

1.5.5 A list of certified major equipment of an air lubrication system for drag reduction is shown in Table 1.5.5.

List of Certified Equipment Table 1.5.5

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	Pump	X	-	-	X	O	-	X	
2	Air blower	X	-	X	O	O	-	X	
3	Air compressor	X	-	X	O	O	-	X	
4	Class I, II pressure vessel	X	-	-	-	-	X	X	
5	Class III pressure vessel	X	-	-	-	-	O	X	
6	Motors (50kW and over)	X	-	-	X	O	-	X	
7	Motors (below 50kW)	-	X	-	X	-	-	X	
8	Electrical control box	X	-	-	-	-	-	X	
No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	

9	Frequency converter	X	-	-	X	O	-	X	Frequency converter of 50kW and over
10	Pipes of greater than 50 mm in diameter and fittings (flanges, bends, T-junction, etc.) used in class I, II piping systems	X	-	-	-	-	X	-	
11	Pipes of less than 50 mm in diameter and fittings (flanges, bends, T-junction, etc.) used in class I, II piping systems	-	X	-	-	-	X	-	
12	Pipes and fittings (flanges, bends, T-junction, etc.) used in class III piping system	-	X	-	-	-	X	-	
13	Valves of 50 mm and above in diameter used in class I, II piping systems; valves of 300 mm and above in diameter used in class III piping system; sea valves	X	-	-	X	O	-	X	
14	Valves of less than 50 mm in diameter used in class I, II piping systems	-	X	-	X	-	-	X	

1.6 Surveys

1.6.1 General requirements

1.6.1.1 The installation of an air lubrication system for drag reduction is to meet the requirements of the Guidelines and the approved plans. Equipment of the system is to meet the requirements of 1.5 of the Chapter for certification. Surveys and tests are to be carried out according to the requirements of this Section after installation and the class notation ALDR may be assigned upon satisfactory surveys and tests.

1.6.2 Surveys during construction

1.6.2.1 Openings on the hull are to be examined and tightness test is to be carried out in

accordance with the requirements of 4.3.1 of Section 3 of Chapter 4, PART ONE of ISC Rules for Classification of Sea-Going Steel Ships.

1.6.2.2 The manufacture, installation and testing of piping, including the strength test in the workshop and the tightness test after installation onboard the ship.

1.6.2.3 If the valves of the air lubrication system for drag reduction fall within the definition of ship-side valve, requirements of 2.8.9 “Ship-side valves and fittings” of PART THREE of ISC Rules for Classification of Sea-Going Steel Ships are to be met.

1.6.2.4 Equipment and piping of the air lubrication system for drag reduction are to be examined after installation to confirm that the arrangement, installation and fabrication technology are in compliance with the requirements of the approved plans.

1.6.2.5 Functional tests for the air lubrication system for drag reduction and associated equipment and piping are to be carried out.

1.6.2.6 If deemed necessary by the field surveyor, a sea trial test may be carried out to confirm that the ship is not adversely affected by air layer/bubble and its distribution (e.g. influence on sea chest and water lubricated bearing).

1.6.2.7 For ships for which the EEDI calculation and verification are required, the sea trial is to be carried out according to the requirements of Chapter 3.

1.6.3 Surveys after construction

1.6.3.1 Annual survey

(1) Overall examination is to be carried out for the air lubrication system for drag reduction and its associated equipment and piping to confirm that they are in a good working condition.

(2) Random check of the control, monitoring and alarm functional tests is to be carried out for the control and monitoring system.

(3) It is to be confirmed that the safety protection devices of the pressure vessels of the air lubrication system for drag reduction with the working pressure of 0.7Mpa and over are in good working condition.

(4) The non-return devices in way of sea opening of the air layer/bubble generator (or non-return valves connecting air pipe and air layer/bubble generator) are to be examined to confirm that they are in good condition.

(5) The ingress alarm device in the space where the air layer/bubble generator locates is to be examined (if any).

1.6.3.2 Surveys of the outside of the ship’s bottom/in-water surveys

(1) Relevant openings for the air lubrication system for drag reduction on the hull are to be examined so as to confirm that they are in good condition.

(2) External accessories of the hull in relation to the air lubrication system for drag reduction are to be examined so as to confirm that they are in good condition.

1.6.3.3 Intermediate survey

The survey items are same as those of the annual survey in 1.6.3.1.

1.6.3.4 Special survey

(1) All annual survey items in 1.6.3.1.

(2) Air compressors and safety devices of the air lubrication system for drag reduction are to be surveyed.

(3) Pressure vessels of the air lubrication system for drag reduction with the working pressure of 0.7Mpa and over together with its accessories and valves are to be opened for examination and

pressure test is to be carried out if corrosion or damage is found so as to determine its working pressure. If it is difficult to open the pressure vessel of 0.7Mpa and over for examination, a hydraulic pressure test at 1.25 times the working pressure may be carried out as an alternative.

(4) Internal examination is to be carried out for spaces where air supply devices and air layer/bubble generators locate (if provided).

CHAPTER 2 CONSTRUCTION AND SYSTEMS

2.1 General provisions

2.1.1 An air lubrication system for drag reduction normally consists of air supply device, air supply piping, air layer/ bubble generator, air escape protector and monitoring and control system as shown in Figure 2.1.1. Air compressor and air reservoir may be taken as air supply device. For ships with shallow draft, an air blower with appropriate pressure may be used for direct air supply.

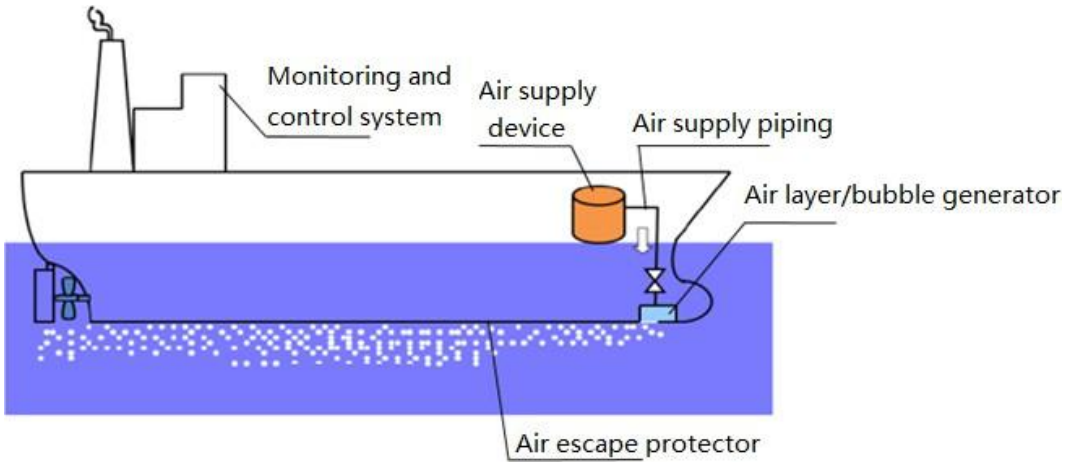

Figure 2.1.1 Construction of air lubrication system for drag reduction

2.1.2 Air lubrication system for drag reduction is to be capable of maintaining continuous normal operation under the design environmental condition.

2.1.3 Air layer/bubble generator is to be so installed as not to affect the normal operation of the energy converter of odometer or depth gauge.

2.1.4 Oil content in the air layer/bubble for drag reduction outside the shell is to be minimized and ISO 8573-1, Class 4 is to be satisfied as a minimum.

2.1.5 Redundancy configuration is normally not required for specific equipment assigned with class notation ALDR.

2.1.6 Longitudinal strength

2.1.6.1 For modified ships, the influence of the installation of air lubrication system for drag reduction on the longitudinal strength is to be evaluated.

2.1.6.2 If additional opening is provided in the shell plating, the calculation of hull girder sectional properties is to comply with the requirements of ISC Rules for Classification of Sea-Going Steel Ships for openings. The openings are to be so arranged as to minimize the effect on longitudinal strength and are not to be arranged in the same transverse section as far as possible.

2.1.7 Subdivision and stability

2.1.7.1 The intact stability and damage stability of ships installed with air lubrication system for drag reduction are to meet the relevant requirements of Chapter 1, PART TWO of ISC Rules for Classification of Sea-Going Steel Ships.

2.1.7.2 For ships under conversion to add air lubrication system for drag reduction, the effect on the lightship weight and its center of gravity and the stability information after installation of the system is to be assessed. And the assessment is used to determine whether the ship shall be re-inclined and whether to submit the stability manual, damage stability calculations and loading instrument for re-approval.

2.2 Air supply device

2.2.1 If the air supply device is fitted in an enclosed space from which air is drawn, the ventilation of the space is to be arranged by taking into full consideration of the air consumption requirements of air lubrication system for drag reduction and cooling requirements of mechanical equipment.

2.2.2 If the air supply device is fitted in a dedicated enclosed space, the ventilation system of the space is normally to be installed with a safety device to keep the ventilation system in operation during the operation of air supply device.

2.2.3 A dedicated air compressor is normally to be provided for air lubrication system for drag reduction. If other air supply device is used, the actual consumption of air is to be taken into full consideration in the design stage, particularly not to affect the needs for air of the starting and control systems of propulsion and its auxiliary machinery.

2.2.4 The air blower is to meet the recognized industry standards and is to be capable of operating under specified marine environmental conditions.

2.2.5 Air compressor and air reservoir

2.2.5.1 If the discharge pipe of the dedicated air compressor is connected with the air reservoir, gas and liquid separator is to be fitted between the dedicated air compressor and air reservoir to separate and drain the liquid contained in the compressed air discharged from the compressor.

2.2.5.2 Pressure gauge and safety valve are to be fitted for dedicated air compressor and the opening pressure of the safety valve is not to be greater than 1.1 times the working pressure. Safety valve or safety diaphragm is to be fitted on the water jacket wall of the compressor cooler.

2.2.5.3 A relief valve is to be fitted to the crank case of the dedicated air compressor when the crankcase has a volume exceeding 0.6 m^3.

2.2.5.4 The design and manufacture of dedicated air reservoir are to comply with the relevant provisions of Sections 2 & 4 and appendix 4 of Chapter 6, PART THREE of ISC Rules for Classification of Sea-Going Steel Ships. The air reservoir is to be so installed that the drain pipe operates effectively when the ship is under normal inclining condition.

2.3 Piping system

2.3.1 Means for monitoring and adjusting the flow is to be provided for air supply piping system.

2.3.2 Non-return valves to prevent sea water ingress are to be fitted in way of sea opening of air layer/bubble generator, if not possible, non-return valves may be fitted in the air pipeline before connecting to the air layer/bubble generator which is to be provided with measures to prevent seawater corrosion.

2.3.3 Compressed air or ventilation piping system is to meet the general requirements for pumps

and piping system of ISC Rules for Classification of Sea-Going Steel Ships.

2.3.4 If water-cooling is adopted by the dedicated air compressor or blower, the cooling water piping system is also to meet the applicable requirements of ISC Rules for Classification of Sea-Going Steel Ships.

2.3.5 Hydraulic pressure piping system for remote control of valves is to meet the requirements for hydraulic pressure transmission piping of ISC Rules for Classification of Sea-Going Steel Ships.

2.4 Air layer/bubble generator

2.4.1 Except for special forms, the watertight structural members of air layer/bubble generator are to meet the requirements for shell plating.

2.4.2 Air layer/bubble generator together with its attached hull structures are to be capable of withstanding the design pressure of air ejecting pipe.

2.4.3 If additional openings are fitted in the shell plating, the openings are to be kept clear of stress concentrated area as far as possible and, if not possible, compensation is to be made. Local stress concentration induced by the openings is to be evaluated according to the actual conditions.

2.4.4 Openings in the shell plating are to have well-rounded corners and, if watertight structural members which are open to the sea are to be fitted in way of the shell plating, the thickness of the plating is to be the same as that of the adjacent shell plating.

2.5 Air escape protector

2.5.1 If longitudinal air escape protector is fitted on the shell plating, the escape protection structure is not to be directly welded to the shell plating and discontinuous backing bars are to be fitted on the shell plating. The thickness of backing bars is not to be less than that of the shell plating connected or 14 mm, whichever is the lesser.

2.5.2 Escape protection structure and backing bars are not to be interrupted abruptly but to be gradually tapered at their ends and terminated on a suitably stiffened panel.

2.5.3 All butts of escape protection structure, backing bars and shell plating are to be properly shifted from one another.

2.6 Power supply and electrical system

2.6.1 The electrical system and electrical installations of air lubrication and drag reduction system are to comply with the applicable requirements of Chapter 2, PART FOUR of ISC Rules for Classification of Sea-Going Steel Ships.

2.6.2 Electrical load analysis

2.6.2.1 The number and capacity of generator sets onboard a ship applying for the class notation ALDR are to comply with the requirements of 2.1.1.1 of Chapter 2, PART FOUR of ISC Rules for Classification of Sea-Going Steel Ships.

2.6.2.2 The electrical loading evaluation of air lubrication and drag reduction system is to be submitted for approval and is to be included in the “Electrical loading evaluation of main and emergency sources of electrical power” required to be submitted in 1.1.3.1 of Chapter 1, PART FOUR of ISC Rules for Classification of Sea-Going Steel Ships.

2.7 Monitoring and control

2.7.1 Monitoring and control functions are to be provided for air lubrication and drag reduction system so that the operation of the system to be kept within a predetermined parameter range indifferent operational conditions.

2.7.2 The following operational parameters for the air lubrication and drag reduction system are to be displayed locally and, if applicable, in the remote station:

(1) Air compressor/blower operational status;

(2) Opening and closing of air supply valves or opening extent;

(3) Air flow;

(4) Air reservoir pressure;

(5) Air supply pressure prior to air layer/bubble generator;

(6) System alarms;

(7) System shutdown and emergency stop.

2.7.3 The computer-based control system for air lubrication and drag reduction is, as a Category II system, to comply with the relevant requirements in Section 6 of Chapter 2, PART SEVEN of ISC Rules for Classification of Sea-Going Steel Ships.

2.7.4 If the air layer/bubble generator is installed in a pipe tunnel, installation of an ingress alarm device in this space is to be considered.

CHAPTER 3 EEDI CALCULATION AND VERIFICATION

3.1 General provisions

3.1.1 The Chapter aims to provide relevant calculation methods and verification guidance for ships applying for incorporating the energy saving effect of air lubrication system for drag reduction into the Attained EEDI value.

3.1.2 The Chapter is a supplement for ships installed with air lubrication system for drag reduction on the basis of ISC Rules for Green Eco-Ships and Guidelines for Verification of The Energy Efficiency Design Index (EEDI) of Ships and provides basis for assigning the class notation CD_x for CO_2 emission design index of green ships.

3.1.3 According to the limits on the usage of innovative energy efficient technologies during navigation, air lubrication system for drag reduction may be deemed as continuously available[①].

3.2 Scope of application

3.2.1 The Chapter applies to sea-going ships applying for class notation CD_x for CO_2 emission design index as specified in ISC Rules for Green Eco-Ships.

3.2.2 For sea-going ships engaged on international voyages, the applicable ship types and definitions are given in Chapter 2 of Part One of ISC Rules for Green Eco-Ships.

3.2.3 For sea-going ships engaged on domestic voyages, the applicable ship types and definitions are given in Chapter 4 of Part Two of ISC Rules for Green Eco-Ships.

3.3 Method for calculation of EEDI of ships installed with air lubrication system for drag reduction

① Refer to MEPC.1/Circ.815 on Guidelines on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of Attained EEDI.

3.3.1 Attained EEDI calculation formula:

3.3.1.1 For ships installed with air lubrication system for drag reduction, a common formula for calculation of Attained EEDI is adopted as follows:

$$\frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}{}^{*}\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}{}^{**}\right)}{f_i \cdot f_c \cdot f_i \cdot Capacity \cdot f_w \cdot V_{ref} \cdot f_m}$$

(formula 3-1)

* If part of the Normal Maximum Sea Load is provided by shaft generators, for that part of the power, SFC_{ME} and C_{FME} may be used instead of SFC_{AE} and C_{FAE}.

When $0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)} \leq P_{AE}$, $P_{AE}.C_{FAE}.SFC_{AE}$ may be replaced by:

$$(P_{AE} - 0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)}).C_{FAE}.SFC_{AE} + 0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)}.C_{FME(i)}.SFC_{ME(i)}$$

When $0.75 * \sum_{i=1}^{nPTO} P_{PTO(i)} > P_{AE}$, $P_{AE}.C_{FAE}.SFC_{AE}$ may be replaced by:

$$P_{AE}.C_{FME(i)}.SFC_{ME(i)}$$

** In case of $P_{PTI(i)} > 0$, the average weighted value of (SFC_{ME}·C_{FME}) and (SFC_{AE}·C_{FAE}) is to be used for calculation of P_{eff}.

3.3.2 Definition and selection of parameters in Attained EEDI calculation formula

3.3.2.1 For ships installed with air lubrication system for drag reduction, other than the calculation of the contribution of the system to EEDI, other calculations are to be carried out according to Appendix 1 of ISC Rules for Green Eco-Ships.

3.3.2.2 Propulsion power of main engine ($P_{ME(i)}$), conversion factor between fuel consumption and CO_2 of main engine ($C_{FME(i)}$), certified specific fuel consumption ($SFC_{ME(i)}$) of the main engine, power of auxiliary engine (P_{AE}), conversion factor between fuel consumption and CO_2 of auxiliary engine (C_{FAE}), certified specific fuel consumption (SFC_{AE}) of the auxiliary engine, Capacity, correction factor for ship specific design elements (f_j), capacity correction factor (f_i), cubic capacity correction factor (f_c), factor for speed reduction at sea (f_w), and power of shaft motor ($P_{PTI(i)}$) are to be selected according to Appendix 1 of ISC Rules for Green Eco-Ships.

3.3.2.3 V_{ref} is the ship speed, measured in knot, on deep water in the condition corresponding to the propulsion power of main engine ($P_{ME(i)}$) and Capacity as selected in paragraph 3.3.2.2 when the air lubrication system for drag reduction is OFF and assuming the weather is calm with no wind and no waves.

3.3.2.4 The reduction of propulsion power induced by air lubrication system for drag reduction is expressed as P_{eff} , multiplied by the availability factor of the technology f_{eff}, and then multiplied by C_{FME} and SFC_{ME} (if $P_{PTI(i)} > 0$, the average weighted value of (SFC_{ME}·C_{FME}) and (SFC_{AE}·C_{FAE}) is to be used) , and then deducted from the EEDI formula.

3.3.2.5 Where, P_{eff} is calculated according to formula 3-2 as follows:

$$P_{eff} = P_{PeffAL} - P_{AEeffAL} \times \frac{CF_{AE}}{CF_{ME}} \times \frac{SFC_{AE}}{SFC_{ME}}$$

(formula 3-2)

where:

(1) P_{PeffAL} , in kW, is the reduction of propulsion power due to the operation of air lubrication

system for drag reduction under the condition corresponding to the Capacity as defined in Appendix 1 of ISC Rules for Green Eco-Ships (hereinafter referred to as 'fully loaded condition'). P_{PeffAL} is to be calculated in fully loaded condition and sea trial condition.

(2) $P_{AEeffAL}$, in kW, is the additional auxiliary power required for the operation of air lubrication system for drag reduction in fully loaded condition. $P_{AEeffAL}$ is to be calculated with 75% rated output power of air blower or air compressor according to the system testing report. If the applicant can provide detailed calculation process or test report of $P_{AEeffAL}$ to the verifier, $P_{AEeffAL}$ may be calculated according to the average value of the consumption power of air blower or air compressor measured during steady running in practical operation in fully loaded condition on deep water and assuming the weather is calm with no wind and no waves.

(3) SFC_{ME} is the certified specific fuel consumption of the main engine at 75% of rated power. If two and more main engines are installed onboard the ship, average weighted value of 75% of the rated power and specific fuel consumption of each engine is to be taken.

(4) SFC_{AE} is the certified specific fuel consumption of the auxiliary engine at 50% of rated power. If two and more auxiliary engines are installed onboard the ship, average weighted value of 50% of the rated power and specific fuel consumption of each engine is to be taken.

3.4 Verification of the contribution of air lubrication system for drag reduction to EEDI

3.4.1 Verification procedures

3.4.1.1 For ships installed with air lubrication system for drag reduction, at first, EEDI is to be verified according to ISC Guidelines for Verification of the Energy Efficiency Design Index (EEDI) of Ships.

3.4.1.2 Verification of air lubrication system for drag reduction is to be carried out according to the additional requirements of 3.4.2 and 3.4.3.

3.4.1.3 The propulsion power deduction P_{PeffAL} for final determination of the contribution of air lubrication system for drag reduction to EEDI must be verified by the verifier.

3.4.1.4 If simulated calculation or test value is adopted for the additional auxiliary power $P_{AEeffAL}$ needed for the running of air lubrication system for drag reduction, this value also must be verified by the verifier.

3.4.2 Preliminary verification at the design stage

3.4.2.1 In addition to the requirements of ISC Guidelines for Verification of the Energy Efficiency Design Index (EEDI) of Ships, the EEDI technical files to be submitted by the applicant are also to include:

(1) Schematic of air lubrication system for drag reduction;

(2) The reduction of propulsion power P_{PeffAL} due to the air lubrication system for drag reduction at the speed of V_{ref} in fully loaded condition and sea trial condition respectively;

(3) The reduction rate of propulsion power EDR_{full} in fully loaded condition due to the air lubrication system for drag reduction. EDR_{full} is calculated by dividing $P_{MEeffAL}$ by P_{ME} in Appendix 1 of ISC Rules for Green Eco-Ships in the fully loaded condition (see Figure 3.4.2);

(4) The reduction rate of propulsion power EDR_{trial} in sea trial condition due to the air lubrication system for drag reduction. EDR_{trial} is predicted by dividing $P_{MEeffAL}$ by P_{ME} in Appendix 1 of ISC Rules for Green Eco-Ships in the sea trial condition (see Figure 3.4.2);

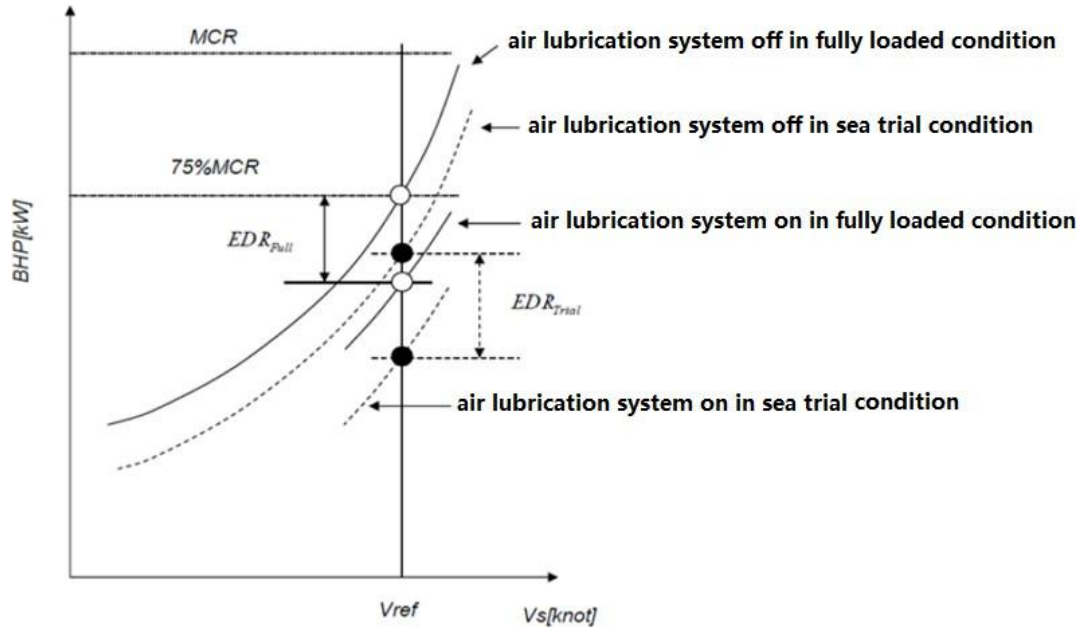

Figure 3.4.2 Prediction of the Reduction Rate of Propulsion Power due to Air lubrication and drag reduction system

(5) additional auxiliary power $P_{AEeffAL}$ needed for running air lubrication system for drag reduction;

(6) calculation process and preliminary result of Attained EEDI of ships installed with air lubrication system for drag reduction .

3.4.2.2 In addition to the requirements of ISC Guidelines for Verification of the Energy Efficiency Design Index (EEDI) of Ships, additional information that the verifier may request the applicant to provide includes:

(1) the detailed calculation process of the reduction of propulsion power P_{PeffAL} due to the air lubrication system for drag reduction;

(2) the detailed calculation process of the additional auxiliary power $P_{AEeffAL}$ needed for the running of air lubrication system for drag reduction.

3.4.2.3 Speed tank test is to be carried out first for ships equipped with air lubrication system for drag reduction as that for conventional ships.

3.4.2.4 At the design stage, model test is to be carried out to measure or calculate the reduction of propulsion power due to the air lubrication system and drag reduction in order to obtain the reduction of propulsion power P_{PeffAL} due to the system.

3.4.2.5 If the sea trial test is intended to be carried out for a ship at the sea trial stage in fully loaded condition, 3.4.2.4 may be exempted with the consent of the shipowner and shipyard and a report is to be sent to ISC.

3.4.2.6 Numerical calculations may be accepted as equivalent to model tests. After the model test of a ship with the air lubrication system for drag reduction OFF is carried out, numerical calculations are to be carried out to evaluate the delivered power of propeller in resistance and self-propulsion conditions with the air lubrication and drag reduction system ON, and relevant evaluation report is to be submitted. Numerical calculations may include the CFD calculation of resistance and self-propulsion at the reference speed V_{ref} and the change of hull resistance and

self-propulsion factor.

3.4.2.7 At the design stage, the additional auxiliary power needed for the running of the air lubrication system for drag reduction is to be calculated in order to obtain the additional auxiliary power $P_{AEeffAL}$ necessary for the running of the system.

3.4.2.8 Model test

(1) The test procedures and quality control system of the model test organization on air lubrication for drag reduction are to be verified. If the lack of previous experience is revealed, the verifier is to audit the quality control system of the model test organization.

(2) If the quality control system of the model test organization on air lubrication for drag reduction is not certified with valid documents (e.g.: ISO 9001), the following additional information on the model test organization is to be submitted to the verifier:

a. description of the facilities and equipment of the model test lab on air lubrication for drag reduction, including the name of facilities, details of equipment and calibration record for each monitoring equipment;

b. major facilities and equipment for the model test on air lubrication for drag reduction include but not limited to: air blower, resistance dynamometer, flowmeter, pressure sensor, underwater camera system etc.;

(3) The model test on air lubrication for drag reduction is to follow the principles of geometric similarity, hydrostatic similarity (displacement, weight and center of gravity), motion similarity and partial dynamic similarity. During the model test, the Froude Number of model ship is equal to that of the actual ship, the advance coefficient of model propeller is equal to that of the actual propeller and the Reynolds Number of the test is to exceed the critical Reynolds Number.

(4) Appropriate scale ratio of test model is to be set as far as possible provided that the above similarities are met simultaneously and the processing accuracy of the test model is to meet the requirements of test procedures.

(5) Test conditions and measurement requirements

a. Loading condition of model test: the test is at least to be carried out in fully loaded condition. If sea trial of an actual ship in fully loaded condition is not possible, an additional model test condition corresponding to the actual ship sea trial condition is required.

b. The test at least includes resistance and self-propulsion test (fully loaded condition, sea trial condition) when the air lubrication system for drag reduction is OFF. Resistance and self-propulsion test (fully loaded condition, sea trial condition) when the air lubrication system for drag reduction is ON. Different amount of ejected air flow is to be selected for the test.

c. Measurement parameters at least include resistance, air flow, electrical power, bottom pressure and bottom air layer observation and measurement.

(6) Handling of test data

a. The contribution of air lubrication system for drag reduction to EEDI is determined by comparing the relative values and the absolute values of propulsion power.

b. Contribution of the air lubrication system for drag reduction to EEDI is estimated according to the model test result, however, the estimated result can only be used as a reference, while the final EEDI is to be attained after the actual ship sea trial.

3.4.3 Final verification at sea trial stage

3.4.3.1 In addition to ISC Guidelines for Verification of The Energy Efficiency Design Index (EEDI) of Ships, EEDI technical files to be submitted by the applicant for the final verification

at the sea trial stage are to include:

(1) arrangement of air lubrication system for drag reduction (as built);

(2) configuration specifications of relevant equipment of air lubrication system for drag reduction (as built);

(3) control strategy/operation plan of air lubrication system for drag reduction (if any);

(4) real ship measurement data in sea trial condition when air lubrication system for drag reduction is ON/OFF, real ship data correction process and result in fully loaded condition when air lubrication system for drag reduction is OFF and real ship data correction process and result in fully loaded condition when air lubrication system for drag reduction is ON;

(5) the amended calculation process and final result of the Attained EEDI of ships installed with air lubrication system for drag reduction.

3.4.3.2 For verification of EEDI for ships installed with air lubrication system for drag reduction, the final verification at the sea trial stage is to prevail. At sea trial stage, real ship sea trial verification is to be carried out for the reduction ratio of propulsion power due to the air lubrication system for drag reduction attained at the design stage.

3.4.3.3 Before the commencement of sea trial, the sea trial team is to develop a reasonable and feasible sea trial plan (including measurement method) and submit it to the ISC' surveyor for review and the sea trial verification test for air lubrication system for drag reduction can only be carried out after the satisfactory review of the plan.

3.4.3.4 Requirements for sea trial

(1) The sea trial is to be carried out according to the speed trial requirements of ISO15016:2015. Ideal sea condition is to be selected in the test as far as possible to keep the rolling angle of the ship less than 0.5°.

(2) First, general speed trial of EEDI is to be carried out. In the general speed trial, the air lubrication system for drag reduction is OFF, i.e., the propulsion power is not reduced.

(3) Then, provided that the loading and floating of ship is not changed and the sea condition is kept as the same as far as possible, the air lubrication system for drag reduction is ON and the speed trial is carried out.

3.4.3.5 ISC site surveyor is to witness the sea trial and to confirm the test and measured data as required in 3.4.3.4.

3.4.3.6 Sea trial data correction

(1) Data analysis is to be carried out according to ISO15016:2015 and speed – power curves in sea trial condition when the air lubrication system for drag reduction is ON/OFF are to be developed respectively.

(2) If the V_{ref} obtained in the sea trial is different from the predicted value at the design stage when the air lubrication system for drag reduction is OFF, the power reduction rate of the main engine in fully loaded condition and in sea trial condition is to be re-calculated according to the value of the power corresponding to V_{ref} obtained from sea trial.

(3) Analysis is to be made based on the data measured in sea trial to draw the speed-power curve when the air lubrication system for drag reduction is ON.

(4) The actual reduction rate ADR_{trial} of propulsion power at V_{ref} in sea trial is to be calculated.

(5) If the sea trial is not conducted in fully loaded condition, the reduction rate of propulsion power in this condition is to be calculated according to formula 3-3 as follows:

$$1 - ADR_{Full} = (1 - EDR_{Full}) \times \frac{1 - ADR_{Trial}}{1 - EDR_{Trial}}$$

namely:

$$ADR_{Full} = 1 - (1 - EDR_{Full}) \times \frac{1 - ADR_{Trial}}{1 - EDR_{Trial}}$$

(formula 3-3)

(6) The reduction of propulsion power P_{PeffAL} due to the air lubrication system for drag reduction in fully loaded condition and in sea trial condition are to be calculated according to formulas 3-4 and 3-5 as follows:

$$P_{PeffAL\_Full} = ADR_{Full} \times P_P$$

(formula 3-4)

$$P_{PeffAL\_Trial} = ADR_{Trial} \times P_P$$

(formula 3-5)

as shown Figure 3.4.3.

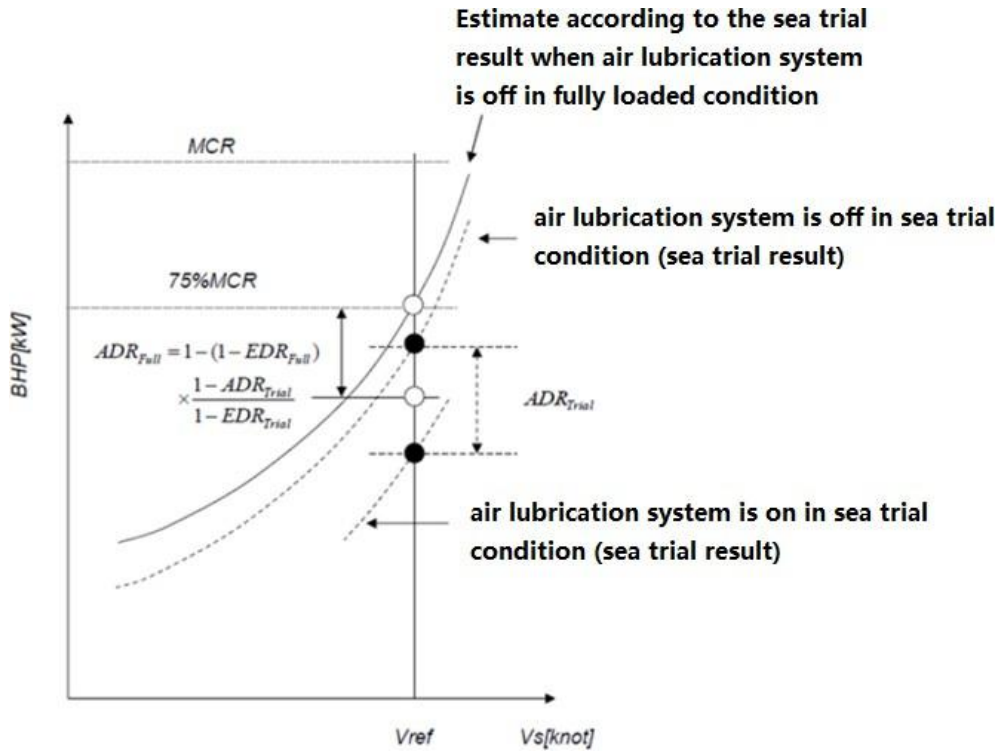

Figure 3.4.3 Calculation of the Actual Reduction Rate of Propulsion Power due to Air lubrication system for drag reduction

3.4.3.7 EEDI technical files are to be revised according to the sea trial result when necessary. The amendment is to include:

(1) speed (V_{ref}), in case that it is different from the predicted value at the design stage;

(2) the reduction of propulsion power P_{PeffAL} when the air lubrication system for drag reduction is ON in fully loaded condition and in sea trial condition and the speed is V_{ref};

(3) the reduction rate of propulsion power (ADR_{full} and ADR_{trial}) due to air lubrication system for drag reduction in fully loaded condition and sea trial condition;
(4) the calculated EEDI value when the air lubrication system for drag reduction is ON in fully loaded condition.