RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part I Ships Operating in Polar Waters, Polar Class Ships and Ice Class Ships

Rules for the Survey and Construction of Steel Ships
Part I 2018 AMENDMENT NO.1
Guidance for the Survey and Construction of Steel Ships
Part I 2018 AMENDMENT NO.1

Rule No.134 / Notice No.103 25 December 2018
Resolved by Technical Committee on 1 August 2018

ClassNK
NIPPON KAIJI KYOKAI

An asterisk (*) after the title of a requirement indicates that there is also relevant information in the corresponding Guidance.

RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

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Part I Ships Operating in Polar Waters, Polar Class Ships and Ice Class Ships

2018 AMENDMENT NO.1

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Rule No.134　　25 December 2018
AMENDMENT TO THE RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Rules for the survey and construction of steel ships" has been partly amended as follows:

Part I　SHIPS OPERATING IN POLAR WATERS, POLAR CLASS SHIPS AND ICE CLASS SHIPS

Amendment 1-1

Chapter 1　GENERAL

1.1　General

1.1.1　Application

Sub-paragraph -5 has been amended as follows.

5　Where a ship is intended to be registered as an ice class vessel (hereinafter referred to as "ice class ship" in this Part) for navigation of the Northern Baltic complying with the *Finnish-Swedish Ice Class Rules 2010* or in the Canadian Arctic complying with the *Arctic Shipping Safety and Pollution Prevention Regulations*, the materials, hull structures, equipment and machinery of the ship are to be in accordance with the requirements in **Chapter 1** except for **1.3** to **1.5** and **Chapter 8** of this Part in addition to those in other Parts.

Chapter 8　ICE CLASS SHIPS

8.1　General

8.1.1　Application*

Sub-paragraph -2 has been amended as follows.

2　The requirements in this Chapter are framed for the ice strengthening of ships which are intended to navigate in the Northern Baltic complying with the *Finnish-Swedish Ice Class Rules 2010* or in the Canadian Arctic complying with the *Arctic Shipping Safety and Pollution Prevention Regulations*.

8.1.2 Maximum and Minimum Draught

Sub-paragraph -6 has been amended as follows.

6 The minimum forward draught is not to be less than that obtained from the following formula.

$(2.0 + 0.00025\Delta)h_0\ (m)$ but need not exceed $4h_0$

where

Δ : The displacement of the ship ~~at the maximum draught amidships on the *UIWL*.~~ (t) determined from the waterline on the *UIWL*. Where multiple waterlines are used for determining the *UIWL*, the displacement is to be determined from the waterline corresponding to the greatest displacement.

h_0 : Constant given in **Table I8.1** according to the respective ice class

EFFECTIVE DATE AND APPLICATION (Amendment 1-1)

1. The effective date of the amendments is 25 December 2018.

Amendment 1-2

Chapter 1 GENERAL

1.1 General

1.1.1 Application

Sub-paragraph -5 has been amended as follows.

5 Where a ship is intended to be registered as an ice class vessel (hereinafter referred to as “ice class ship” in this Part) for navigation of the Northern Baltic complying with the *2017 Finnish-Swedish Ice Class Rules* ~~*2010*~~ or in the Canadian Arctic complying with the *Arctic Shipping Pollution Prevention Regulations*, the materials, hull structures, equipment and machinery of the ship are to be in accordance with the requirements in **Chapter 1** except for **1.3** to **1.5** and **Chapter 8** of this Part in addition to those in other Parts.

1.2 Definitions

Paragraph 1.2.2 has been amended as follows.

1.2.2 Ice Class Ships*

When the requirements in **Chapter 8** of this Part are applied, the definitions of terms and symbols which appear in this Part are to be as specified in the following **(1)** to **(~~3~~4)**, unless specified elsewhere.

((1) and (2) are omitted.)

(3) The engine output (H) is the total Maximum Continuous output of the engine. If the output of the propulsion machinery is restricted by technical means or by any regulations applicable to the ship, H is to be taken as the restricted output. If additional power sources are available for propulsion power (e.g. shaft motors), in addition to the power of the main engine(s), they are also to be included in the total engine output.

(4) Blade order

Product of number of rotations multiplied by number of blades

Chapter 8 ICE CLASS SHIPS

8.1 General

8.1.1 Application*

Sub-paragraph -2 has been amended as follows.

1 The requirements in this Chapter apply to hull structure, equipment and machinery, etc. of ice class ships.
2 The requirements in this Chapter are framed for the ice strengthening of ships which are intended to navigate in the Northern Baltic complying with the *2017 Finnish-Swedish Ice Class Rules* ~~*2010*~~ or in the Canadian Arctic complying with the *Arctic Shipping Pollution Prevention Regulations*.

Section 8.4 has been amended as follows.

8.4 Fundamental Requirements of Machinery

8.4.1 Materials

1 Materials for Machinery Parts exposed to Seawater

Materials exposed to seawater, such as propeller blades, propeller hub and blade bolts are to have an elongation of not less than 15% for the *U*14*A* test specimens given in **Part K**. Materials other than bronze and austenitic steel are to have an average impact energy value of 20 *J* at -10°C for the *U*4 test specimens given in **Part K**. For nodular cast iron, average impact energy of 10 *J* at -10°C is required accordingly.

2 Materials for Machinery Parts exposed to Seawater Temperatures

Materials exposed to seawater temperatures are to be of steel or other ductile material approved by the Society. The materials are to have an average impact energy value of 20 *J* at -10°C for the U4 test specimens given in **Part K**. The nodular cast iron of a ferrite structure type may be used for relevant parts other than bolts. The average impact energy for nodular cast iron is to be a minimum of 10 *J* at -10°C.

8.4.2 Engine Output

1 The engine output (*H*) is not to be less than the greater of two outputs determined by the following formula for the maximum draught amidships referred to as the *UIWL* and the minimum draught referred to as the *LIWL*, and in no case less than 1,000*kW* for ice class ships with I*A*, I*B*, I*C* and I*D*, and not less than 2,800*kW* for ice class ships with I*A Super*.

$$H = K_e \frac{\left(R_{CH}/1000\right)^{3/2}}{D_P}$$

H : Engine output (*kW*)
K_e : Constant given in **Table I8.10**

Table I8.10 Value of Constant K_e

Propeller type or machinery	CPP or Electric or Hydraulic propulsion machinery	FPP
1 Propeller	2.03	2.26
2 Propellers	1.44	1.60
3 Propellers	1.18	1.31

D_p : Diameter (m) of the propeller

R_{CH} : The resistance (N) of the ship in a channel with brash ice and a consolidated layer

$$R_{CH} = C_1 + C_2 + C_3 C_\mu \left(H_F + H_M\right)^2 \left(B + C_\psi H_F\right) + C_4 L_{PAR} H_F^2 + C_5 \left(LT / B^2\right)^3 \left(A_{wf} / L\right)$$

L : Length (m) of the ship between the perpendiculars on the *UIWL*

B : Maximum breadth (m) of the ship on the *UIWL*

T : Actual ice class draughts (m) of the ship, in general being a draught amidships of length L_f corresponding to the *UIWL* according to **1.2.1(23)** and a draught amidships of length L_f corresponding to the *LIWL* according to **1.2.1(24)**.

~~In any case,~~ If the value of the term $\left(LT / B^2\right)^3$ is ~~not to be taken as~~ less than 5, the value 5 is to be used and ~~not to be taken as~~ if the value of the term is more than 20, the value 20 is to be used.

L_{PAR} : Length (m) of the parallel midship body, measured horizontally between the fore and aft ends of the flat side on the waterline at the actual ice class draught, see **Fig. I8.4**

L_{BOW} : Length (m) of the bow, measured horizontally between the fore end of the flat side on the waterline at the actual ice class draught and the fore perpendicular at the *UIWL*, see **Fig. I8.4.**

A_{wf} : Area (m^2) of the waterline of the bow at the actual ice class draught, see **Fig. I8.4**.

$\psi = \arctan\left(\tan\varphi_2 / \sin\alpha\right)$ (deg)

φ_1, φ_2, α : The angle (deg) between the ship and the water plane at the actual ice class draught, see **Fig. I8.4**. If the ship has a bulbous bow then φ_1 is taken as 90 *degrees*.

C_1 and C_2 : Coefficient taken into account a consolidated upper layer of the brash ice and are to be taken as the followings.

(1) For I*A Super* ice class ships

$$C_1 = f_1 B L_{PAR} / \left(2T / B + 1\right) + \left(1 + 0.021\varphi_1\right)\left(f_2 B + f_3 L_{BOW} + f_4 B L_{BOW}\right)$$

$$C_2 = \left(1 + 0.063\varphi_1\right)\left(g_1 + g_2 B\right) + g_3\left(1 + 1.2T / B\right) B^2 / \sqrt{L}$$

(2) For I*A*, I*B*, I*C* and I*D* ice class ships

$C_1 = 0$

$C_2 = 0$

C_3, C_4 and C_5 : Value given in **Table I8.11**

C_μ : Value given by the following formula, but in no case less than 0.45

$$C_\mu = 0.15\cos\varphi_2 + \sin\psi\sin\alpha$$

C_ψ : Value given by the following formula, but taken as 0 where $\psi \leq 45°$

$$C_\psi = 0.047\psi - 2.115$$

f_1, f_2, f_3, f_4, g_1, g_2 and g_3 : Value given in **Table I8.11**

H_M : Thickness (m) of the brash ice in a channel as given by the followings.

(1) For I*A Super* and I*A* ice class ships $H_M = 1.0$

(2) For I*B* ice class ships $H_M = 0.8$

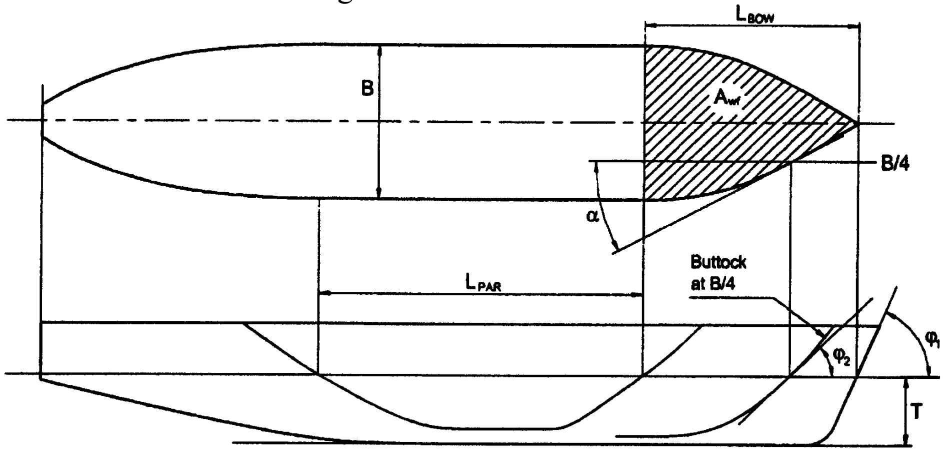
(3) For I*C* ice class ships $H_M = 0.6$

(4) For I*D* ice class ships $H_M = 0.5$

H_F : Thickness (*m*) of the brash ice layer displaced by the bow as given by the following formula.

$$H_F = 0.26 + (H_M B)^{0.5}$$

Fig. I8.4 Dimensions



~~Table I8.10 Value of Constant K_e~~

~~Propeller type or machinery~~	~~CPP or Electric or Hydraulic propulsion machinery~~	~~FPP~~
~~1 Propeller~~	~~2.03~~	~~2.26~~
~~2 Propellers~~	~~1.44~~	~~1.60~~
~~3 Propellers~~	~~1.18~~	~~1.31~~

Table I8.11 Value of $f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4, C_5$

f_1:	23.0 (N/m^2)	g_1:	1,530 (N)	C_3:	845 (N/m^3)
f_2:	45.8 (N/m)	g_2:	170 (N/m)	C_4:	42 (N/m^3)
f_3:	14.7 (N/m)	g_3:	400 ($N/m^{1.5}$)	C_5:	825 (N/m)
f_4:	29.0 (N/m^2)				

2 Special Requirements for Existing Ships

For I*A Super* and I*A* ice class ships which are at beginning stage of construction before 1 September 2003, the engine output (*H*) is to comply with the requirements specified in **-1** above or equivalent requirements by 1 January in the year when 20 *years* have elapsed since the year the ship was delivered. <u>If the ship does not comply with the requirements specified in **-1** on the date given above, the highest lower ice class for which the engine output is sufficient can be confirmed for the ship.</u> When, for an existing ship, values for some of the hull form parameters required for the calculation method specified in **-1** above are difficult to obtain, the following alternative formulae may be used. The dimensions of the ship, defined below, are measured on the *UIWL* as defined in **1.2.1(23)**.

$$H = K_e \frac{(R_{CH}/1000)^{3/2}}{D_P}$$

H : Engine output (kW)

K_e : Constant given in **Table I8.10**
D_P : Diameter of the propeller (*m*)
R_{CH} : The resistance of the ship in a channel with brash ice and a consolidated layer (*N*)

$$R_{CH} = C_1 + C_2 + C_3 \left(H_F + H_M \right)^2 \left(B + 0.658 H_F \right) + C_4 L H_F^2 + C_5 \left(LT / B^2 \right)^3 \left(B / 4 \right)$$

L : Length (*m*) of the ship between the perpendiculars
B : Maximum breadth (*m*) of the ship
T : Actual ice class draught (*m*) of the ship

~~However,~~ If the value of the term $\left(LT / B^2 \right)^3$ is ~~not to be taken as~~ less than 5, the value 5 is to be used and ~~not to be taken as~~ if the value of the term is more than 20, the value 20 is to be used.

C_1 and C_2 : Coefficient taken into account a consolidated upper layer of the brash ice and are to be taken as the followings.

(1) For I*A Super* ice class ships and ice class ships with a bulbous bow

$$C_1 = f_1 BL / \left(2T / B + 1 \right) + 2.89 \left(f_2 B + f_3 L + f_4 BL \right)$$

$$C_2 = 6.67 \left(g_1 + g_2 B \right) + g_3 \left(1 + 1.2T / B \right) B^2 / \sqrt{L}$$

(2) For I*A Super* ice class ships and ice class ships without a bulbous bow

$$C_1 = f_1 BL / \left(2T / B + 1 \right) + 1.84 \left(f_2 B + f_3 L + f_4 BL \right)$$

$$C_2 = 3.52 \left(g_1 + g_2 B \right) + g_3 \left(1 + 1.2T / B \right) B^2 / \sqrt{L}$$

(3) For I*A* ice class ships

$C_1 = 0$ and $C_2 = 0$

$f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4$, and C_5 : Value given in **Table I8.12**

H_M : Thickness (*m*) of the brash ice in a channel as given by the followings.

$$H_M = 1.0$$

H_F : Thickness (*m*) of the brash ice layer displaced by the bow as given by the following formula.

$$H_F = 0.26 + \left(H_M B \right)^{0.5}$$

Table I8.12 Value of $f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4, C_5$

f_1:	10.3 (N/m^2)	g_1:	1,530 (N)	C_3:	460 (N/m^3)
f_2:	45.8 (N/m)	g_2:	170 (N/m)	C_4:	18.7 (N/m^3)
f_3:	2.94 (N/m)	g_3:	400 ($N/m^{1.5}$)	C_5:	825 (N/m)
f_4:	5.8 (N/m^2)				

3 For ships having features of which, there is ground to assume that they will improve the performance of the ship when navigation in ice ~~or ships parameter values of which defined in -1 above are beyond the range given in **Table I8.13**~~, the values for K_e or R_{CH} defined in **-1** and **-2** above may be obtained from detailed calculations or model tests provided that it gives a minimum speed of 5 *knots* in brash ice channels as specified in the following **(1)** to **(5)**:

(1) For I*A Super* ice class ships: 1.0*m* of the brash ice and a 0.1*m* thick consolidated layer of ice
(2) For I*A* ice class ships: 1.0*m* of the brash ice
(3) For I*B* ice class ships: 0.8*m* of the brash ice
(4) For I*C* ice class ships: 0.6*m* of the brash ice
(5) For I*D* ice class ships: 0.5*m* of the brash ice

~~Table I8.13 The Range of Parameters~~

~~Parameter~~	~~Minimum~~	~~Maximum~~
~~α (deg)~~	~~15~~	~~55~~
~~φ_1 (deg)~~	~~25~~	~~90~~
~~φ_2 (deg)~~	~~10~~	~~90~~
~~L (m)~~	~~65.0~~	~~250.0~~
~~B (m)~~	~~11.0~~	~~40.0~~
~~T (m)~~	~~4.0~~	~~15.0~~
~~L_{BOW} / L~~	~~0.15~~	~~0.40~~
~~L_{PAR} / L~~	~~0.25~~	~~0.75~~
~~D_P / T(1)~~	~~0.45~~	~~0.75~~
~~$A_{wf} / (LB)$~~	~~0.09~~	~~0.27~~

~~Note:~~

~~(1) When calculating D_P/T, T is a draught amidships of length L_f corresponding to the *UIWL*.~~

8.4.3 Rudders and Steering Arrangements*

1 The rudder scantlings of rudder post, rudder stock, pintles, steering gear etc. are to comply with requirements in **Chapter 3** of **Part C** and **Chapter 15, Part D**. In this case, the maximum service speed of the ship to be used in these calculations is not to be taken less than that given in the **Table I8.1~~4~~3**.

(-2 and -3 are omitted.)

4 For I*A Super* and I*A* ice class ships, the rudders and steering arrangements are to be designed as follows to endure the loads that work on the rudders by the ice when backing into an ice ridge.

(1) Relief valves for hydraulic pressure are to be installed.

(2) The components of the steering gear (e.g. rudder stock, rudder coupling, rudder horn etc.) are to be dimensioned to withstand loads causing ~~the~~ yield ~~torque~~ stresses within the required diameter of the rudder stock.

(3) Suitable arrangements such as rudder stoppers are to be installed.

Table I8.1~~4~~3 Minimum Speed

Class	Speed (*kt*)
I*A Super*	20
I*A*	18
I*B*	16
I*C*	14
I*D*	14

Section 8.5 has been amended as follows.

8.5 Design Loads of Propulsion Units (Ice Classes I*A Super*, I*A*, I*B* and I*C*)

8.5.1 General

1 The requirements in **8.5** apply to I*A Super*, I*A*, I*B* and I*C* ice class ships.

2 In the design of the propeller, propulsion shafting system and power transmission system, the following are to be taken into account.

(1) Maximum backward blade force

(2) Maximum forward blade force

(3) Maximum blade spindle torque

(4) Maximum propeller ice torque

(5) Maximum propeller ice thrust
(6) Design torque on propulsion shafting system
(7) Maximum thrust on propulsion shafting system
(8) Blade failure load

3 The loads specified in **-2** above are to comply with the following:

(1) The ice loads cover open and ducted-type propellers ~~situated at the stern of ships having~~ with a controllable pitch or fixed pitch blades (including propellers of azimuthing thrusters). ~~Ice loads on bow propellers and pulling type propellers are to receive special consideration and ice loads due to ice impact on the bodies of azimuthing thrusters are not covered by this Chapter.~~ However, the load models of these loads do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially).

(2) The given loads in this chapter are expected, single occurrence, maximum values for the whole ships service life for normal operation conditions. The loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

(3) The loads are total loads (unless otherwise stated) during interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only.

4 Design Loads of Propellers

(1) The loads given are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction. The presented maximum loads are based on a worst case scenario that occurs once during the service life of the ship.

(2) The F_b and F_f specified in **8.5.2** and **8.5.3** originate from different propeller/ice interaction phenomena, and do not occur simultaneously. Hence, they are to be applied separately to one blade.

(3) If the highest point of the propeller is not ~~fully submerged~~ at a depth of at least h_0 below the water surface when the ship is in the ballast condition, the propulsion system is to be designed according to Ice Class I*A* for Ice Classes I*B* and I*C*.

5 The local strength of the thruster (azimuthing and fixed) body are to be sufficient to withstand local ice pressure when the thruster body is designed for extreme loads.

8.5.2 Maximum Backward Blade Force

1 The maximum backward blade force which bends a propeller blade backwards when a propeller mills an ice block while rotating ahead is to be given by the following formulae:

(1) For open propellers:

when $D \le D_{limit} = 0.85\left(H_{ice}\right)^{1.4} (m)$

$$F_b = 27\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \quad (kN)$$

when $D > D_{\mathrm{limit}} = 0.85\left(H_{ice}\right)^{1.4} (m)$

$$F_b = 23\left(H_{ice}\right)^{1.4}\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D \quad (kN)$$

(2) For ducted propellers:

when $D \le D_{\mathrm{limit}} = 4H_{ice} (m)$

$$F_b = 9.5\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2 \quad (kN)$$

when $D > D_{\mathrm{limit}} = 4H_{ice} (m)$

$$F_b = 66\left(H_{ice}\right)^{1.4}\left(\frac{n}{60}D\right)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3}D^{0.6} \quad (kN)$$

where

F_b: Maximum backward blade force for the ship's service life (kN)
Direction of the backward blade force resultant taken perpendicular to chord line at radius $0.7R$. (See Fig. **I8.5**)

H_{ice}: Ice thickness (m) specified in **Table I8.1~~5~~4**.

D : Propeller diameter (m)

EAR : Expanded blade area ratio

d : external diameter of propeller hub (at propeller plane) (m)

Z : number of propeller blades

n : Nominal rotational propeller speed (rpm) at maximum continuous revolutions in free running condition for controllable pitch propellers and 85% of the nominal rotational propeller speed at maximum continuous revolutions in free running condition for fixed pitch propellers

Table I8.1~~5~~4 The Thickness of the Ice Block H_{ice}

	I*A Super*	I*A*	I*B*	I*C*
Thickness of the design maximum ice block entering the propeller H_{ice} (m)	1.75	1.5	1.2	1.0

(-2 is omitted.)

(8.5.3 and 8.5.4 are omitted.)

8.5.5 Frequent Distributions for Propellers Blade Loads

1 A Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in **Fig. I8.6**, is to be used for the fatigue design of blades.

$$P\left(\frac{F_{ice}}{\left(F_{ice}\right)_{max}} \geq \frac{F}{\left(F_{ice}\right)_{max}}\right) = \cancel{e^{\left(-\left(\frac{F}{\left(F_{ice}\right)_{max}}\right)^k \ln\left(N_{ice}\right)\right)}}\ \underline{\exp\left(-\left(\frac{F}{\left(F_{ice}\right)_{max}}\right)^k \ln\left(N_{ice}\right)\right)}$$

where

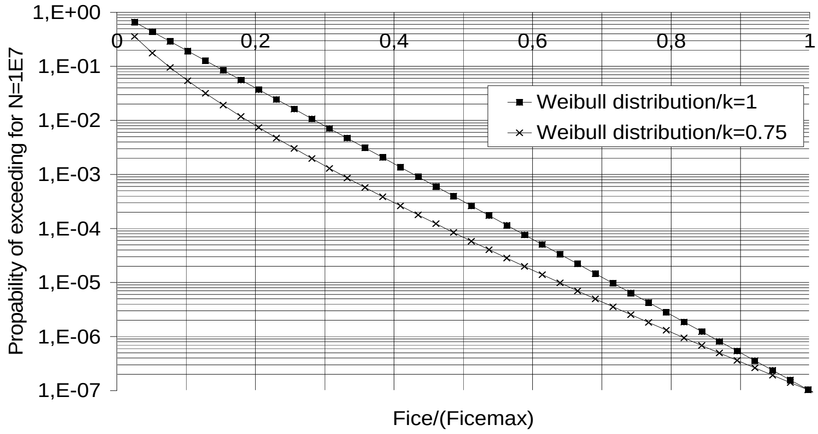
F_{ice} : Random variable for ice loads (kN) on the blade, and meet the requirements $0 \leq F_{ice} \leq \left(F_{ice}\right)_{max}$

$(F_{ice})_{max}$: Maximum ice load for the ship's service life (kN)

k : Shape parameter for Weibull-type distribution The following definitions apply:
Open propeller: k =0.75
Ducted propeller: k =1.0

N_{ice} : Total number of ice loads on a propeller blade for the ship's service life

Fig.I8.6 The Weibull-type Distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$) that is Used for Fatigue Designs



2 Number of ice loads

(1) The number of load cycles per propeller blade in the load spectrum ~~shall~~ is to be determined according to the formula:

$$N_{ice} = k_1 k_2 k_3 \cancel{k_4} N_{class} \frac{n_n}{60}$$

where

N_{class}: Reference number of loads for ice classes, as specified in **Table I8.1~~6~~5**

n_n : Nominal propeller rotational speed at maximum continuous revolutions in free running condition (rpm)

k_1 : Propeller location factor, as specified in **Table I8.1~~7~~6**

~~k_2 : Propeller type factor, as specified in **Table I8.18**~~

~~k_3 : Propulsion type factor, as specified in **Table I8.19**~~

Table I8.1~~6~~5 Reference Number of Loads for Ice Classes N_{class}

Class	I*A Super*	I*A*	I*B*	I*C*
impacts in life / (n_n/60)	$9 \cdot 10^6$	$6 \cdot 10^6$	$3.4 \cdot 10^6$	$2.1 \cdot 10^6$

Table I8.1~~7~~6 Propeller Location Factor k_1

factor	Centre propeller Bow first operation	Wing propeller Bow first operation	Pulling propeller (wing and centre) Bow propeller or Stern first operation
k_1	1	~~1.35~~2	3

~~Table I8.18 Propeller Type Factor k_2~~

~~factor~~	~~open propeller~~	~~ducted propeller~~
~~k_2~~	~~1~~	~~1.1~~

~~Table I8.19 Propulsion Type Factor k_3~~

~~factor~~	~~fixed~~	~~azimuthing~~
~~k_3~~	~~1~~	~~1.2~~

$k_{\cancel{4}2}$: The submersion factor $k_{\cancel{4}2}$ is determined from the equation.

$$
k_{\cancel{4}\underline{2}} = \begin{cases} 0.8 - f & : f < 0 \\ 0.8 - 0.4f & : 0 \le f \le 1 \\ 0.6 - 0.2f & : 1 < f \le 2.5 \\ 0.1 & : f > 2.5 \end{cases}
$$

where

$$
f = \frac{h_{\cancel{0}\underline{a}} - H_{ice}}{D/2} - 1
$$

<u>k_3 : The propulsion machinery type factor k_3 is as follows.</u>

<u>Fixed propulsor: $k_3 = 1$</u>

<u>Azimuthing propulsor: $k_3 = 1.2$</u>

$h_{\cancel{0}\underline{a}}$: The depth of the propeller centreline at the lower ice waterline (*LIWL*) of the ship (*m*)

H_{ice} and D : As specified in **8.5.2**

(2) In the case of components that are subject to loads resulting from propeller/ice interaction with all of the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

8.5.6 (Omitted)

8.5.7 Design Thrust along Propulsion Shaft Lines

The design thrust along the propeller shaft line is to be given by the following formulae:

(1) Maximum shaft thrust forwards:

$T_r = T + 2.2T_f$ (kN)

(2) Maximum shaft thrust backwards:

$T_r = 1.5T_b$ (kN)

where:

T_b and T_f : Maximum propeller ice thrust (*kN*) determined in **8.5.6**

T: Propeller bollard thrust (*kN*). If not known, T is to be taken as specified in **Table I8.~~20~~<u>17</u>**

Table I8.~~20~~<u>17</u> Value of T

Propeller type	T
Controllable pitch propellers (open)	$1.25\,T_n$
Controllable pitch propellers (ducted)	$1.1\,T_n$
Fixed pitch propellers driven by turbine or electric motor	T_n
Fixed pitch propellers driven by diesel engine (open)	$0.85\,T_n$
Fixed pitch propellers driven by diesel engine (ducted)	$0.75\,T_n$

Note:

T_n : Nominal propeller thrust (*kN*) at maximum continuous revolutions in free running open water conditions

8.5.8 Maximum Propeller Ice Torque

The maximum propeller ice torque applied to the propeller <u>during the service life of the ship</u> is to be given by the following formulae:

(1) For open propellers:

when $D \le D_{\text{limit}} = 1.8H_{ice}$ (m)

$$
Q_{max} = 10.9\left(1 - \frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^3 \quad (kNm)
$$

when $D > D_{\text{limit}} = 1.8H_{ice}$ (m)

$$Q_{max} = 20.7\left(H_{ice}\right)^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^{1.9} \quad (kNm)$$

(2) For ducted propellers:

when $D \leq D_{\text{limit}} = 1.8H_{ice} \quad (m)$

$$Q_{max} = 7.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^{3} \quad (kNm)$$

when $D > D_{\text{limit}} = 1.8H_{ice} \quad (m)$

$$Q_{max} = 14.6\left(H_{ice}\right)^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}\left(\frac{n}{60}D\right)^{0.17} D^{1.9} \quad (kNm)$$

where:

H_{ice}, D and d: As specified in **8.5.2**

$P_{0.7}$: Propeller pitch (m) at $0.7R$

In the case of controllable pitch propellers, $P_{0.7}$ is to correspond to maximum continuous revolutions at the bollard condition. If not known, $P_{0.7}$ is to be taken as 0.7 $P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at maximum continuous revolutions at a free running condition.

n : Rotational propeller speed (rpm) at maximum continuous revolutions in the bollard condition

If not known, n is to be taken as specified in **Table I8.~~21~~18**.

Table I8.~~21~~18 Rotational Propeller Speed n

Propeller type	n
Controllable pitch propellers	n_n
Fixed pitch propellers driven by turbine or electric motor	n_n
Fixed pitch propellers driven by diesel engine	$0.85n_n$

Note:

In **Table I8.18**, n_n~~:~~ is ~~N~~nominal rotational speed (rpm) at maximum continuous revolutions at the free running open water condition.

8.5.9 Design Torque on Propulsion Shafting System

~~2~~1 Design torque along propeller shaft line

(1) If there is not a predominant torsional resonance ~~with~~in the ~~designed operating rotational~~ operational speed range ~~extended~~ or in the range 20% above ~~the maximum~~ and 20% below the ~~minimum~~ maximum operating speed~~s~~ (bollard condition), the following estimation of the maximum torque can be used:

Directly coupled two stroke diesel engines without flexible coupling

$$Q_{peak} = Q_{emax} + Q_{vib} + Q_{max}\frac{I_e}{I_t} \quad (kNm)$$

and other plants

$$Q_{peak} = Q_{emax} + Q_{max}\frac{I_e}{I_t} \quad (kNm)$$

Q_{peak}: maximum response torque (kNm)

Q_{emax}: maximum engine torque (kNm)

If the maximum torque, Q_{emax}, is not known, it is to be taken as specified in **Table I8.~~23~~19**

Q_{vib}: vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC)

I_e : equivalent mass moment of inertia of all parts on the engine side of the component under consideration (kgm^2)

I_t : equivalent mass moment of inertia of the whole propulsion system (kgm^2)

(2) If there is ~~a~~ first blade order torsional resonance ~~with~~in the ~~designed operating rotational~~ operational speed range ~~extended~~ or in the range 20% above ~~the maximum~~ and 20% below the ~~minimum~~ maximum operating speed~~s~~ (bollard condition), the design torque ($Q_{~~r~~peak}$) of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line. There are two alternative ways of performing the dynamic analysis as the following **(a)** and **(b)**.

(a) Time domain calculation for estimated milling sequence excitation (**8.5.9-2.**)

(b) Frequency domain calculation for blade orders sinusoidal excitation (**8.5.9-3.**)

Table I8.~~23~~19 Maximum Engine Torque Q_{emax}

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	0.75 Q_n

Notes:

Q_{motor} : Electric motor peak torque (kNm)

Q_n : Nominal torque at ~~MCR~~ maximum continuous revolutions in free running condition (kNm)

~~Q_r : Maximum response torque along the propeller shaft line (kNm)~~

~~1~~**2** Time domain calculation

Time domain calculations are to be calculated for the maximum continuous revolutions condition, maximum continuous revolutions bollard conditions and for blade order resonant rotational speeds so that the resonant vibration responses can be obtained. The load sequence given in the following, for a case where a propeller is milling an ice block, are to be used for the strength evaluation of the propulsion line. (The given load sequence is not intended for propulsion system stalling analyses.)

(1) Diesel engine plants without an elastic coupling are to be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in the time domain.

(2) The engine firing pulses are to be included in the calculations and their standard steady state harmonics can be used.

(3) If there is a blade order resonance just above the maximum continuous revolutions speed, calculations are to cover rotational speeds up to 105% of the maximum continuous revolutions speed.

(4) The propeller ice excitation torque for shaft line transient ~~torsional vibration~~ dynamic analysis in the time domain is to comply with the following requirements:

(~~1~~a) The excitation torque is ~~to be described by~~ defined as a sequence of blade impacts which are of half sine shape and occur at the blade. The excitation frequency is to follow the propeller rotational speed during the ice interaction sequence. The total ice torque is to be obtained by summing the torques of single ice blade ice impacts taking into account the phase shift. The single ice blade impact is given by the following formulae: ~~(See **Fig. I8.7**)~~

(~~a~~i) when $0 \le \varphi - 360x \le \alpha_i$ (deg)

$$Q(\varphi) = C_q Q_{max} \sin\left(\varphi\left(180 / \alpha_i\right)\right)$$

(~~b~~ii) when $\alpha_i \le \varphi - 360x \le 360$ (deg)

$Q(\varphi) = 0$

where

φ : Rotation angle from when the first impact occurs

x : Integer revolutions from the time of first impact

Q_{max}: Maximum torque on the propeller as specified in **8.5.8**. Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed, a relevant Q_{max} may be calculated using the relevant speed according to **8.5.8** and **8.5.9**.

C_q: As specified in **Table I8.~~22~~20**

a_i : Duration of propeller blade/ice interaction expressed in rotation angle as specified in **Table I8.~~22~~20** (See **Fig. I8.7**)

Fig.I8.7 Schematic ice torque due to a single blade ice impact as a function of the propeller rotation angle

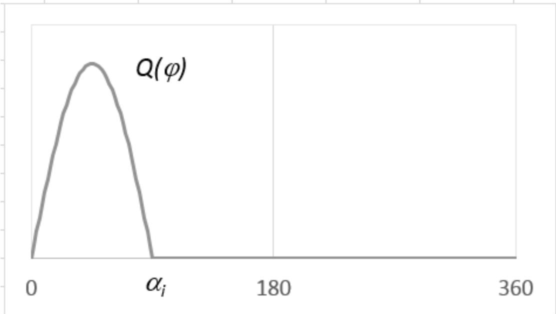


Table I8.~~22~~20 Values of C_q and a_i

Torque excitation	Propeller-ice interaction	C_q	a_i (deg)			
			Z=3	Z=4	Z=5	Z=6
Case 1	Single ice block	0.75	90	90	72	60
Case 2	Single ice block	1.0	135	135	135	135
Case 3	Two ice blocks (phase shift 360/(2~~i~~ · Z) deg.)	0.5	45	45	36	30
Case 4	Single ice block	0.5	45	45	36	30

Note:

Total ice torque is obtained by summing the torque of single blades, while taking ~~into~~ account of the phase shift 360deg./Z (See **Fig. I8.8** and **I8.9**). ~~In addition, a~~At the beginning and ~~at the~~ end of the milling sequence (within the calculated duration), ~~a~~ linear ramp functions ~~for 270 degrees of rotation angle~~ ~~is~~are to be used to increase C_q to its maximum value within one propeller revolution and vice versa to decrease it to zero (see the examples of different Z numbers in **Fig. I8.8** and **I8.9**).

(~~2~~b) The number of propeller revolutions and the number of impacts during the milling sequence are to be given by the following formulae. For bow propellers, the number of propeller revolutions and the number of impacts during the milling sequence are subject to special consideration.

(~~a~~i) The number of propeller revolutions:

$N_Q = 2H_{ice}$

(~~b~~ii) The number of impacts:

ZN_Q

Where

H_{ice} : As specified in **Table I8.15**

Z : Number of propeller blades

An illustration of all excitation cases for different numbers of blades is given in **Fig. I8.8** and **I8.9**.

(c) A dynamic simulation is to be performed for all excitation cases at the operational rotational speed range. For a fixed pitch propeller propulsion plant, a dynamic simulation is also to cover the bollard pull condition with a corresponding rotational speed assuming the maximum possible output of the engine.

(d) For the consideration of loads, the maximum occurring torque during the speed drop process is to be used.

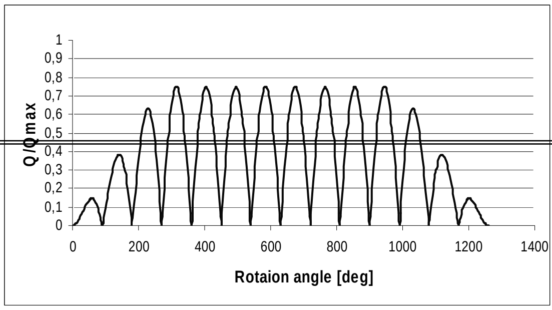
(e) For the time domain calculation, the simulated response torque typically includes the engine mean torque and the propeller mean torque. If this is not the case, the response torques are to be obtained using the following formula:

$$Q_{peak} = Q_{emax} + Q_{rtd}$$

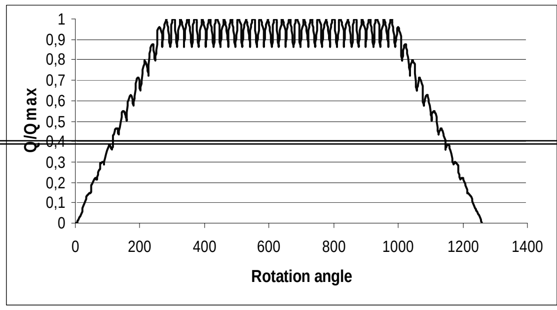
Where

Q_{rtd} : Maximum simulated torque obtained from the time domain analysis

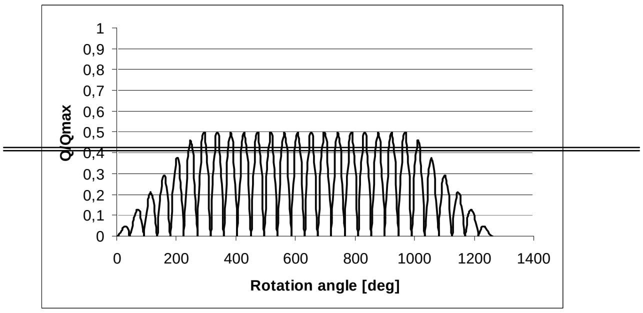
Fig.I8.~~7~~8 Example of the Shape of the Propeller Ice Torque Excitation (three and four bladed propeller)



~~(a) Case 1 Single blade impact($\alpha_1 = 90°$)~~



~~(b) Case 2 Single blade impact($\alpha_1 = 135°$)~~



~~(c) Case 3 Double blade impact ($\alpha_1 = 45°$)~~

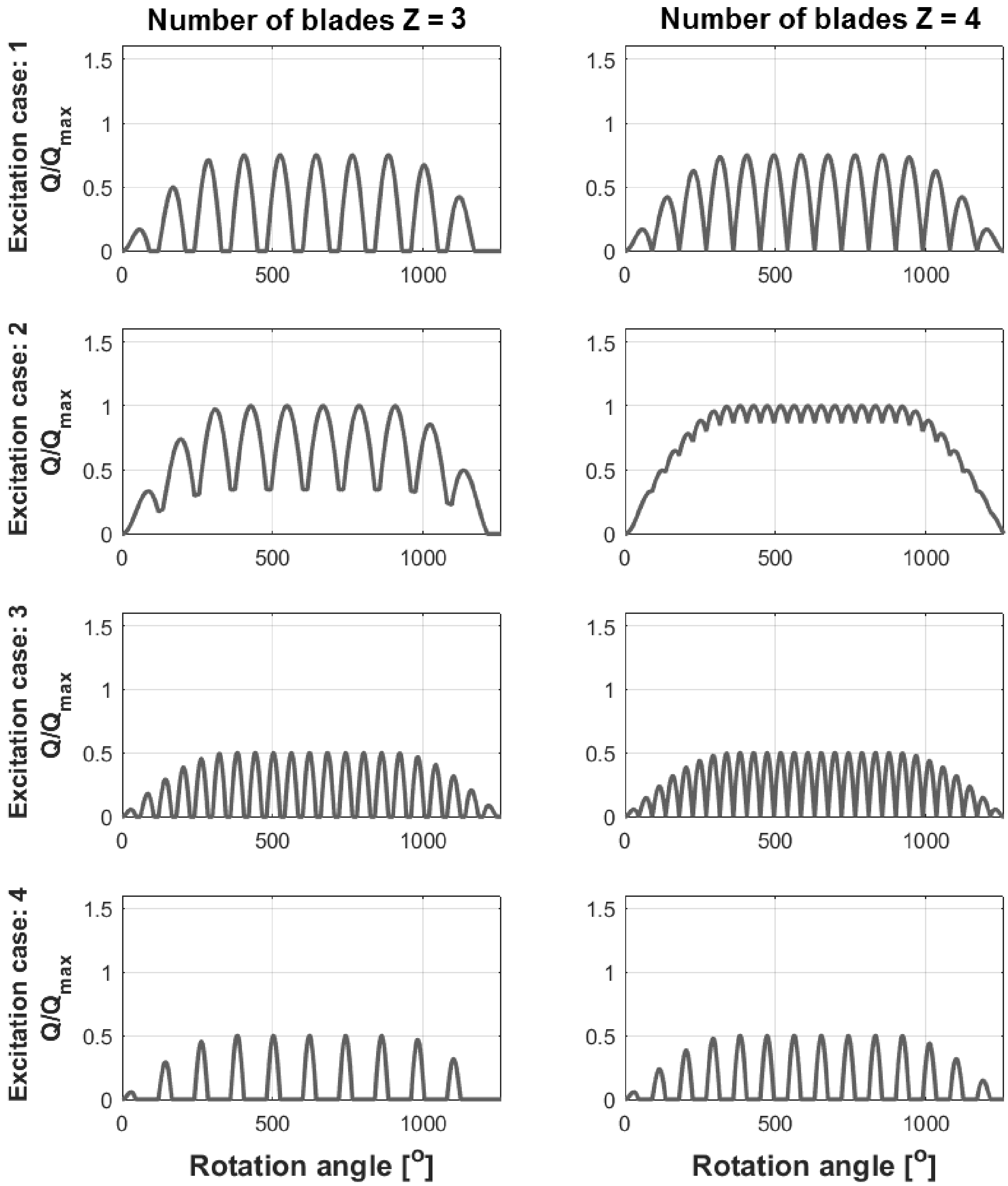
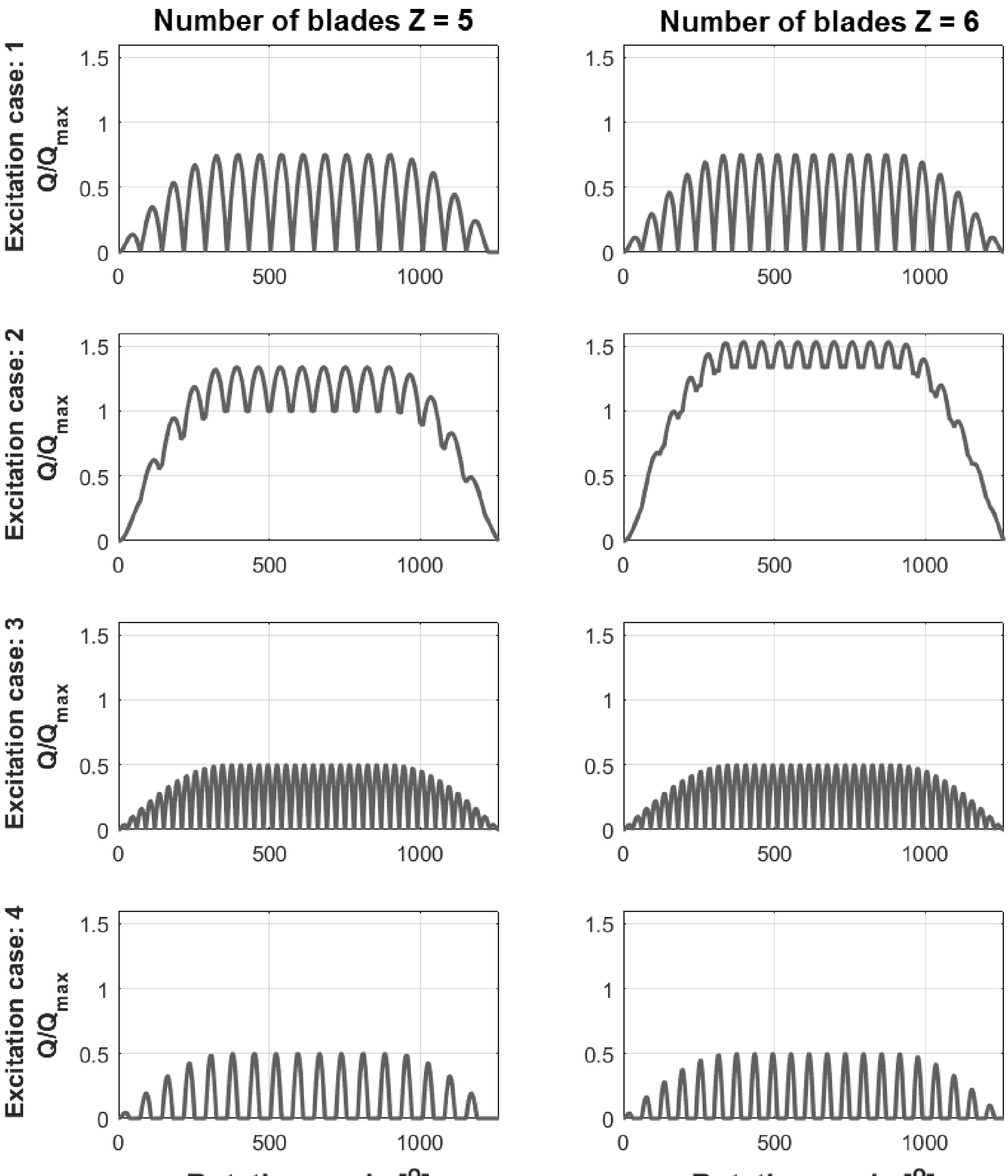

Number of blades Z = 3
Number of blades Z = 4
Excitation case: 1
Excitation case: 2
Excitation case: 3
Excitation case: 4
Q/Q_max
Rotation angle [°]
Rotation angle [°]
0
0.5
1
1.5
0
500
1000

Fig.I8.9 Example of the Shape of the Propeller Ice Torque Excitation (five and six bladed propeller)



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3 Frequency domain calculation

For frequency domain calculations, blade order and twice-the-blade-order excitation may be used. The amplitudes for the blade order and twice-the-blade-order sinusoidal excitation have been derived based on the assumption that the time domain half sine impact sequences were continuous, and the Fourier series components for blade order and twice-the-blade-order components have been derived. The propeller ice torque is then:

$$Q_F(\varphi) = Q_{max}(C_{q0} + C_{q1}\sin(ZE_0\varphi + \alpha_1) + C_{q2}\sin(2ZE_0\varphi + \alpha_2)) \quad (kNm)$$

where

C_{q0}: Mean torque parameter, as specified in **Table I8.21**

C_{q1}: First blade order excitation parameter, as specified in **Table I8.21**

C_{q2}: Second blade order excitation parameter, as specified in **Table I8.21**

α_1, α_2: Phase angles of the excitation component, as specified in **Table I8.21**

φ: Angle of rotation

E_0: Number of ice blocks in contact, as specified in **Table I8.21**

Z: Number of propeller blades

Table I8.21 Values of C_{q0}, C_{q1}, α_1, C_{q2}, α_2, and E_0

Number of propeller blades: Z	Torque excitation	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
3	Case 1	0.375	0.36	-90	0	0	1
	Case 2	0.7	0.33	-90	0.05	-45	1
	Case 3	0.25	0.25	-90	0		2
	Case 4	0.2	0.25	0	0.05	-90	1
4	Case 1	0.45	0.36	-90	0.06	-90	1
	Case 2	0.9375	0	-90	0.0625	-90	1
	Case 3	0.25	0.25	-90	0	0	2
	Case 4	0.2	0.25	0	0.05	-90	1
5	Case 1	0.45	0.36	-90	0.06	-90	1
	Case 2	1.19	0.17	-90	0.02	-90	1
	Case 3	0.3	0.25	-90	0.048	-90	2
	Case 4	0.2	0.25	0	0.05	-90	1
6	Case 1	0.45	0.36	-90	0.05	-90	1
	Case 2	1.435	0.1	-90	0	0	1
	Case 3	0.3	0.25	-90	0.048	-90	2
	Case 4	0.2	0.25	0	0.05	-90	1

The design torque for the frequency domain excitation case is to be obtained using the formula:

$$Q_{peak} = Q_{emax} + Q_{vib} + \left(Q^n{}_{max} C_{q0}\right)\frac{I_e}{I_t} + Q_{rf1} + Q_{rf2}$$

where

Q_{vib}: Vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC)

$Q^n{}_{max}$: Maximum propeller ice torque at the operation speed in consideration

C_{q0}: Value given in **Table I8.21**

Q_{rf1}: Blade order torsional response from the frequency domain analysis

Q_{rf2}: Second order blade torsional response from the frequency domain analysis

If the maximum engine torque, Q_{emax}, is not known, it is to be taken as given in **Table I8.19**. All the torque values have to be scaled to the shaft revolutions for the component in question.

4 For time domain calculation specified in **-2** and frequency domain calculation specified in **-3**, further the requirements given in the following **(1)** to **(3)** are also to be complied with.

(1) The aim of time domain torsional vibration simulations is to estimate the extreme torsional load for the ship's lifespan. The simulation model can be taken from the normal lumped mass

elastic torsional vibration model, including damping. For a time domain analysis, the model should include the ice excitation at the propeller, other relevant excitations and the mean torques provided by the prime mover and hydrodynamic mean torque in the propeller. The calculations should cover variation of phase between the ice excitation and prime mover excitation. This is extremely relevant to propulsion lines with directly driven combustion engines. Time domain calculations are to be calculated for the maximum continuous revolutions condition, maximum continuous revolutions bollard conditions and for resonant speed, so that the resonant vibration responses can be obtained.

(2) For frequency domain calculations, the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load sequences. First and second order blade components should be used for excitation.

(3) The calculation should cover the entire relevant rpm range and the simulation of responses at torsional vibration resonances.

8.5.10 Blade Failure Loads

1 The blade failure load is to be given by the following formula~~:~~ or alternatively by means of an appropriate stress analysis, reflecting the non-linear plastic material behaviour of the actual blade. In such a case, the blade failure area may be outside the root section. A blade is regarded as having failed if the tip is bent into an offset position by more than 10% of propeller diameter *D*.

$$F_{ex} = \frac{300ct^2\sigma_{ref1}}{0.8D-2r} \quad (kN)$$

where

σ_{ref1} : The reference ~~stress~~ strength is to be given by the following formula:

$$\sigma_{ref1} = 0.6\sigma_{0.2} + 0.4\sigma_u \quad (MPa)$$

where

σ_u : Minimum ultimate ~~T~~tensile ~~stress~~ strength of blade material (MPa)

$\sigma_{0.2}$: Minimum ~~Y~~yield ~~stress~~ or 0.2% proof strength of blade material (MPa)

c : Chord length of blade section (m)

F_{ex} : ultimate blade load resulting from blade loss through plastic bending (kN)

r : blade section radius (m)

t : Maximum blade section thickness (m)

2 The force specified in **-1.** above is to be acting at $0.8R$ in the weakest direction of the blade ~~and at a spindle arm of 2/3 the distance of the axis of blade rotation of the leading or trailing edge, whichever is greater~~.

3 Spindle torque

The maximum spindle torque due to a blade failure load acting at $0.8R$ is to be determined. The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation, the maximum spindle torque will occur. This maximum spindle torque is to be defined by an appropriate stress analysis or using the equation given below.

$$Q_{sex} = \max\left(C_{LE0.8}, 0.8C_{TE0.8}\right)C_{spex}F_{ex} \quad (kNm)$$

where

$$C_{spex} = C_{sp}C_{fex} = 0.7\left(1-\left(\frac{4EAR}{z}\right)^3\right)$$

C_{sp} : Non-dimensional parameter taking account of the spindle arm

C_{fex} : Non-dimensional parameter taking account of the reduction of the blade failure force at the location of the maximum spindle torque

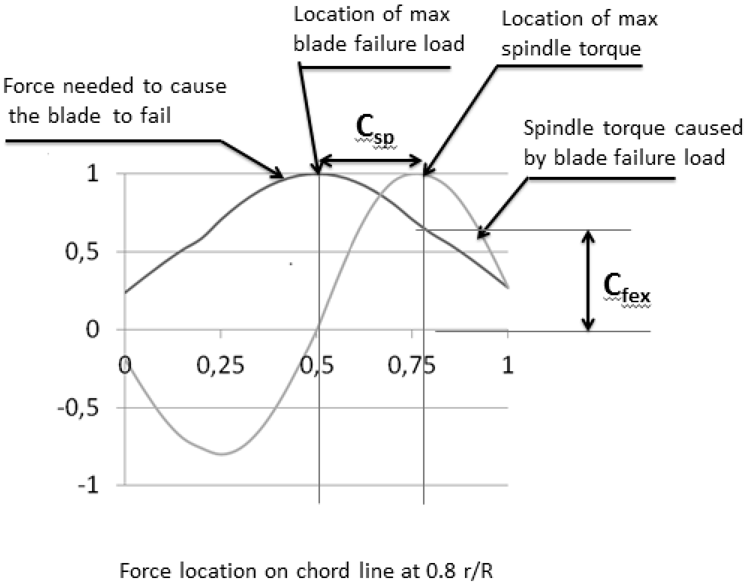
$C_{LE0.8}$: Leading edge portion of the chord length at $0.8R$

$C_{TE0.8}$: Trailing edge portion of the chord length at $0.8R$

If C_{spex} is below 0.3, a value of 0.3 is to be used for C_{spex}.

Fig. I8.10 illustrates the spindle torque values due to blade failure loads across the entire chord length.

Fig.I8.10 Schematic figure showing a blade failure load and the related spindle torque when the force acts at a different location on the chord line at radius $0.8R$



Section 8.6 has been amended as follows.

8.6 Design of Propellers and Propulsion Shafting Systems (Ice Classes I*A Super*, I*A*, I*B* and I*C*)

8.6.1 (Omitted)

8.6.2 Propeller Blade Stresses

1 Propeller blade stresses are to be calculated for the design loads given in **8.5.2** and **8.5.3** using Finite Element Analysis. In the case of a relative radius r/R < 0.5, the blade stresses for all propellers at their root areas may be calculated by the formula given below. Root area dimensions based on this formula can be accepted even if FEM analysis shows greater stresses at the root area.

$$\sigma_{st} = C_1 \frac{M_{BL}}{100ct^2} \quad (MPa)$$

where

C_1 : $\dfrac{\text{stress obtained with FEM analysis result}}{\text{stress obtained with beam equation}}$

If the actual value is not available, C_1 should ~~be taken as~~ have a value of 1.6.

where

M_{BL}: Blade bending moment (kNm), in the case of a relative radius r/R <0.5, the following:

$$M_{BL} = (0.75 - r/R)RF$$

F: ~~Maximum of~~ Force F_b ~~and~~ or F_f, whichever ~~is~~ has greater absolute value.

2 The calculated blade stress σ_{st} specified in **-1** above is to comply with the following:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.\cancel{5}3$$

where

σ_{st}: Maximum stress resulting from F_b or F_f (MPa)

σ_u: Ultimate ~~T~~tensile ~~stress~~ strength of blade material (MPa)

σ_{ref2}: Reference ~~stress~~ strength (MPa), whichever is ~~less~~ lower

$\sigma_{ref2} = 0.7\sigma_u$,or $\sigma_{ref2} = 0.6\sigma_{0.2}+0.4\sigma_u$

3 Fatigue design of propeller blades

(1) The fatigue design of a propeller blade is based on the estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution is to be calculated and the acceptability criterion for fatigue is to be fulfilled as given in ~~this section~~ **-4.**. The equivalent stress is normali~~z~~sed for ~~100 million~~ 10^8 cycles. For materials with a two-slope S-N curve (See **Fig. I8.11**), ~~If the following criterion is fulfilled,~~ the fatigue calculations specified in this section are not required if the following criterion is fulfilled.

$$\sigma_{\exp} \geq B_1 \sigma_{ref2}{}^{B_2} \log\left(N_{ice}\right)^{B_3}$$

where

The coefficients B_1, B_2 and B_3 are as given in the **Table I8.2~~4~~2**.

Table I8.2~~4~~2 The Coefficients B_1, B_2 and B_3

Coefficients	Open propeller	Ducted propeller
B_1	0.002~~70~~46	0.001~~84~~67
B_2	~~1.007~~0.947	~~1.007~~0.956
B_3	2.101	2.470

(2) For the calculation of equivalent stress, two types of S-N curves are to be used.

(a) Two-slope S-N curve (slopes 4.5 and 10), see **Fig. I8.~~8~~11**.

(b) One-slope S-N curve (the slope can be chosen), see **Fig. I8.~~9~~12**.

(3) The type of the S-N curve ~~shall~~ is to be selected to correspond ~~to~~ with the material properties of the blade. If the S-N curve is ~~not~~ unknown, a two-slope S-N curve is to be used.

(4) The equivalent fatigue stress for ~~100 million~~ 10^8 stress cycles which produces the same fatigue damage as the load distribution for the service life of the ship, is:

$$\sigma_{fat} = \rho\left(\sigma_{ice}\right)_{max}$$

where

ρ: Depending on the applicable S-N curve, ρ is to be given by either **(5)** or **(6)**.

$$\left(\sigma_{ice}\right)_{max} = 0.5\left(\left(\sigma_{ice}\right)_{fmax} - \left(\sigma_{ice}\right)_{bmax}\right)$$

$\left(\sigma_{ice}\right)_{max}$: The mean value of the principal stress amplitudes resulting from forward and backward blade forces at the location being studied.

$\left(\sigma_{ice}\right)_{fmax}$: The principal stress resulting from forward load

$\left(\sigma_{ice}\right)_{bmax}$: The principal stress resulting from backward load

(5) The calculation of the parameter ρ for a two-slope S-N curve is as follows:

Parameter ρ relates the maximum ice load to the distribution of ice loads according to the following regression formulae:

$$\rho = C_1 \left(\sigma_{ice}\right)_{max}{}^{C2} \sigma_{fl}{}^{C3} \log\left(N_{ice}\right)^{C4}$$

where

$$\sigma_{fl} = \gamma_{\varepsilon 1}\gamma_{\varepsilon 2}\gamma_v\gamma_m\sigma_{\exp}$$

σ_{fl} : Characteristic fatigue strength for blade material (*MPa*)

$\gamma_{\varepsilon 1}$: The reduction factor ~~for~~ due to scatter (equal to one standard deviation)

$\gamma_{\varepsilon 2}$: The reduction factor for~~and~~ test specimen size effect

γ_v : The reduction factor for variable amplitude loading

γ_m : The reduction factor for mean stress

$\sigma_{\exp}$: The mean fatigue strength of the blade material at 10^8 cycles to failure in seawater (*MPa*)

The following values are to be used as reduction factors if actual values are ~~not~~ unavailable:

$\gamma_\varepsilon = \gamma_{\varepsilon 1}\gamma_{\varepsilon 2} = 0.67$, $\gamma_v = 0.75$, $\gamma_m = 0.75$

The coefficients C_1, C_2, C_3, and C_4 are given in **Table I8.2~~5~~3**. The applicable range of N_{ice} for calculating ρ is $5\times10^6 \le N_{ice} \le 10^8$.

Fig.I8.~~8~~11 Two-slope S-N Curve

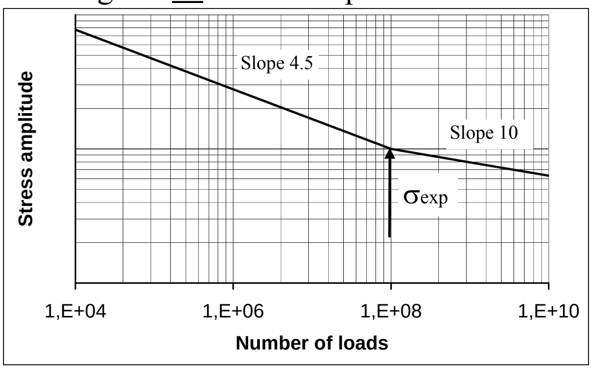


Fig.I8.~~9~~12 Constant-slope S-N Curve

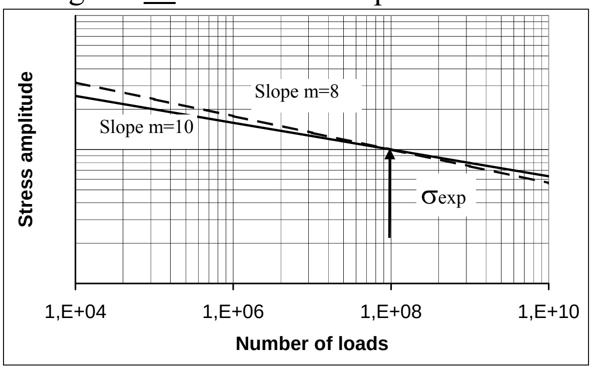


Table I8.2~~5~~3 The Coefficients C_1, C_2, C_3 and C_4

Coefficients	Open propeller	Ducted propeller
C_1	0.0007~~11~~47	0.0005~~09~~34
C_2	0.0645	0.0533
C_3	-0.0565	-0.0459
C_4	2.220	2.584

(6) The calculation of the parameter for a constant-slope S-N curve

In the case of materials with a constant-slope S-N curve - see **Fig. I8.~~9~~12** – the ρ factor is to be calculated using the following formula:

$$\rho = \left(G \frac{N_{ice}}{N_R} \right)^{1/m} \left(\ln \left(N_{ice} \right) \right)^{-1/k}$$

where

k is the shape parameter of the Weibull distribution, it is as follows:

(a) $k = 1.0$ for ducted propellers

(b) $k = 0.75$ for open propellers

N_R: The reference number of load cycles (= 10^8)

The applicable range of N_{ice} for calculating ρ is $5 \times 10^6 \le N_{ice} \le 10^8$.

m: slope for S-N curve in log/log scale

G: Values for the parameter G are given in **Table I8.2~~6~~4**. Linear interpolation may be used to calculate the G value ~~for~~ of m/k ratios other than those given in **Table I8.2~~6~~4**.

Table I8.2~~6~~4 Value for the G Parameter for Different m/k Ratios

m/k	*G*	*m/k*	*G*	*m/k*	*G*	*m/k*	*G*
3	6	5.5	287.9	8	40320	10.5	11.899E6
3.5	11.6	6	720	8.5	119292	11	39.917E6
4	24	6.5	1871	9	362880	11.5	136.843E6
4.5	52.3	7	5040	9.5	1.133E6	12	479.002E6
5	120	7.5	14034	10	3.62~~3~~9E6		

4 Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on a blade has to fulfill the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \ge 1.5$$

8.6.3 (Omitted)

8.6.4 Propulsion Shaft Line

1 The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, ~~shall~~ are to be designed to withstand the propeller/ice interaction axial, bending and torsion loads. The safety factor is to be at least 1.3 against yielding for extreme operational loads, 1.5 for fatigue loads and 1.0 against yielding for the blade failure load.

2 The ~~ultimate load resulting from total blade failure~~ blade failure load as defined in Section **8.5.10** is not to cause yielding in shafts and shaft components. The loading is to consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for bending and torsional stresses.

8.6.5 Azimuthing Main Propulsors

With respect to the ~~design of~~ azimuthing main propulsors, the followings are to be ~~taken into account~~ complied with in addition to the requirements specified in **8.6.1**:

(1) Design principle

(a) Azimuthing thrusters are to be designed for thruster body/ice interaction loads. Load formulae specified in this **8.6.5** are given for estimating once in a lifetime extreme loads on the thruster body, based on the estimated ice condition and ship operational parameters. In this **8.6.5**, the following load scenario types are considered:

i) Ice block impact on the thruster body or propeller hub (See **Fig. I8.13**)

ii) Thruster penetration into an ice ridge that has a thick consolidated layer (See **Fig. I8.13**)

iii) Vibratory response of the thruster at blade order frequency

~~(1) Loading cases which are extraordinary for propulsion units are to be taken into account. The estimation of loading cases is to reflect the operational realities of the ship and the thrusters.~~

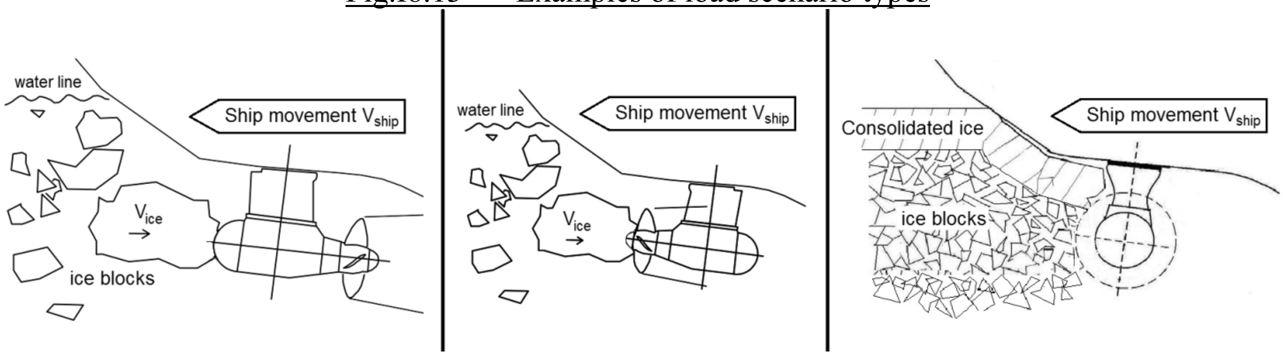
(~~2~~b) The steering mechanism, the fitting of the unit and body of the thruster are to be designed to withstand the ~~loss~~ plastic bending of a blade without damage.

(~~3~~c) The ~~plastic bending~~ loss of a blade is to be ~~considered in~~ taken into account for the propeller blade position, which causes the maximum load on the considered component.

~~(4) Azimuth thrusters are to be designed for the estimated loads specified in **3.5.10** of **Chapter 4** of **Annex 1 "Special Requirements for the Materials, Hull Structures, Equipment and Machinery of Polar Class Ships"**).~~

~~(5) The thickness of an ice sheet is to be taken as the thickness of the maximum ice block entering the propeller, as defined in **Table I8.15**.~~

Fig.I8.13 Examples of load scenario types



Impact on thruster body	Impact on propeller hub	Thruster penetration into the ice ridge

(2) Extreme ice impact loads

(a) The thruster is to withstand the loads occurring when the design ice block defined in **Table I8.14** impacts on the thruster body when the ship is sailing at a typical ice operating speed. Load cases for impact loads are given in **Table I8.25**. The contact geometry is estimated to be hemispherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius is to be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

(b) The ice impact contact load F_{ti} is to be calculated using the following formula. The related parameter values are given in **Table I8.26**. The design operation speed in ice can be derived from **Table I8.27** and **I8.28**, or the ship in question's actual design operation speed in ice can be used. For the pulling propeller configuration, the longitudinal impact speed is used for load case T2 (See **Table I8.25**), impact on hub; and for the pushing propeller unit, the longitudinal impact speed is used for load case T1 (See **Table I8.25**), impact on thruster end cap. For the opposite direction, the impact speed for transversal impact is applied.

$$F_{ti} = C_{DMI} 34.5 R_c^{\,0.5} \left(m_{ice} v_s^{\,2} \right)^{0.333} \ (kN)$$

where

R_c : Impacting part sphere radius (See **Fig. I8.14**)

m_{ice} : Ice block mass (kg)

v_s : Ship speed at the time of contact(m/s)

C_{DMI} : Dynamic magnification factor for impact loads. If unknown, C_{DMI} is to be taken from **Table I8.26**.

For impacts on non-hemispherical areas, such as the impact on the nozzle, the equivalent impact sphere radius R_{ceq} is to be estimated using the equation below.

$$R_{ceq} = \sqrt{\frac{A}{\pi}} \ (m)$$

If the $2R_{ceq}$ is greater than the ice block thickness, the radius is set to half of the ice block thickness. For the impact on the thruster side, the pod body diameter can be used as a basis for determining the radius. For the impact on the propeller hub, the hub diameter can be used as a basis for the radius.

Table I8.25 Load cases for azimuthing thruster ice impact loads

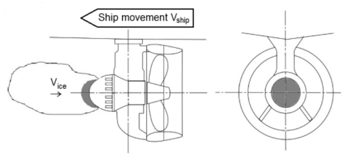
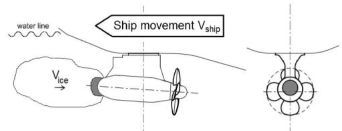
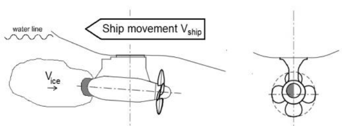
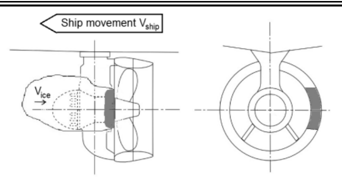
	Force	Loaded area	
Load case T1a Symmetric longitudinal ice impact on thruster	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	 
Load case T1b Non-symmetric longitudinal ice impact on thruster	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area.	
Load case T1c Non-symmetric longitudinal ice impact on nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Contact area is equal to the nozzle thickness (H_{nz}) × the contact height (H_{ice}).	

Table I8.25 Load cases for azimuthing thruster ice impact loads (Continued)

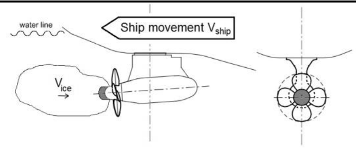
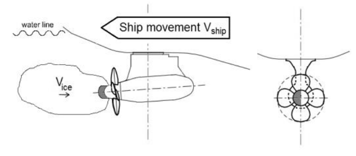
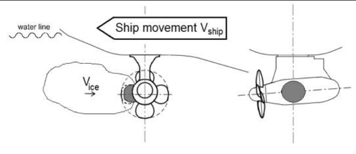
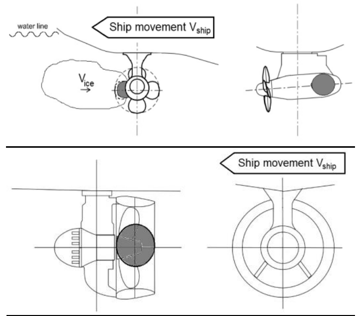
	Force	Loaded area	
Load case T2a Symmetric longitudinal ice impact on propeller hub	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T2b Non-symmetric longitudinal ice impact on propeller hub	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area.	
Load case T3a Symmetric lateral ice impact on thruster body	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T3b Non-symmetric lateral ice impact on thruster body or nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Nozzle contact radius R to be taken from the nozzle length (L_{nz}).	

Fig.I8.14 Dimensions used for R_c

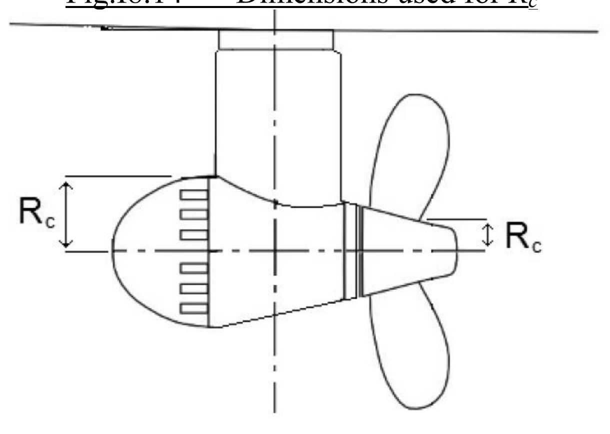


Table I8.26 Value of H_{ice}, m_{ice}, C_{DMI}

	IA Super	IA	IB	IC
Thickness of the design ice block impacting thruster: $2/3H_{ice}$ (m)	1.17	1.0	0.8	0.67
Extreme ice block mass: m_{ice} (kg)	8670	5460	2800	1600
C_{DMI} (if not known)	1.3	1.2	1.1	1

Table I8.27 Impact speeds for aft centerline thruster

Longitudinal impact in main operational direction (*m/s*)	6	5	5	5
Longitudinal impact in reversing direction (*m/s*) (pushing unit propeller hub or pulling unit cover end cap impact)	4	3	3	3
Transversal impact in bow first operation (*m/s*)	3	2	2	2
Transversal impact in stern first operation (double acting ship) (*m/s*)	4	3	3	3

Table I8.28 Impact speeds for aft wing, bow centerline and bow wing thrusters

Longitudinal impact in main operational direction (*m/s*)	6	5	5	5
Longitudinal impact in reversing direction (*m/s*) (pushing unit propeller hub or pulling unit cover end cap impact)	4	3	3	3
Transversal impact (*m/s*)	4	3	3	3

(3) Extreme ice loads on thruster hull when penetrating an ice ridge

The maximum load on thruster hull when penetrating an ice ridge (F_{tr}) is to be estimated for the load cases shown in **Table I8.29**, using the following equation. The parameter values for calculations are given in **Table I8.30** and **I8.31**. The loads are to be applied as uniform distributed load or uniform pressure over the thruster surface. The design operation speed in ice can be derived from **Table I8.30** or **Table I8.31**. Alternatively, the actual design operation speed in ice of the ship in question can be used.

$$F_{tr} = 32 v_s^{0.66} H_r^{0.9} A_t^{0.74} \quad (kN)$$

where

v_s : Ship speed (*m/s*)

H_r : Design ridge thickness (*m*) (the thickness of the consolidated layer is 18% of the total ridge thickness)

A_t : Projected area of the thruster (m^2)

When calculating the contact area for thruster-ridge interaction, the loaded area in the vertical direction is limited to the ice ridge thickness, as shown in **Fig. I8.15**.

Table I8.29 Load cases for azimuthing thruster ridge ice loads

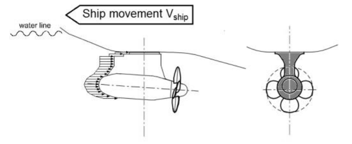
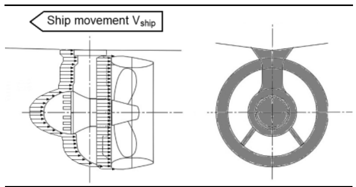
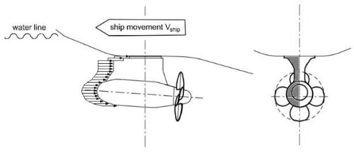
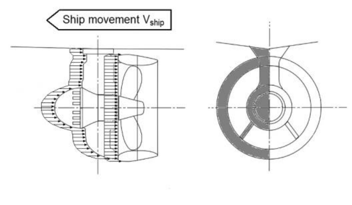
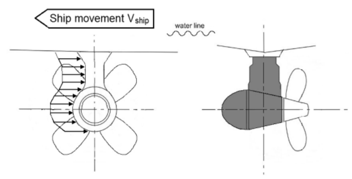
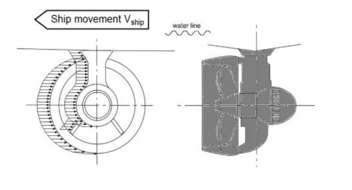
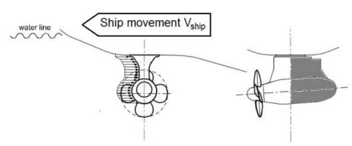
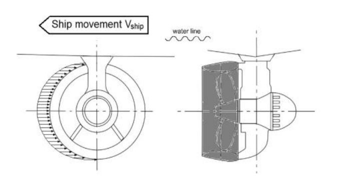
	Force	Loaded area	
Load case T4a Symmetric longitudinal ridge penetration loads	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	 
Load case T4b Non-symmetric longitudinal ridge penetration loads	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area.	 
Load case T5a Symmetric lateral ridge penetration loads for ducted azimuthing unit and pushing open propeller unit	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the contact area.	 
Load case T5b Non-symmetric lateral ridge penetration loads for all azimuthing units	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area.	 

Fig.I8.15 Schematic figure showing the reduction of the contact area by the maximum ridge thickness

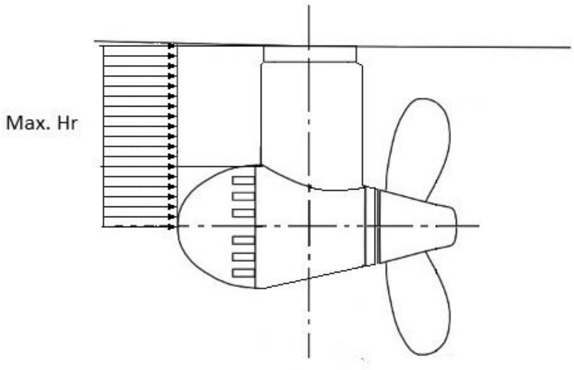


Table I8.30 Parameters for calculating maximum loads when the thruster penetrates an ice ridge (Aft thrusters, Bow first operation)

	IA Super	*IA*	*IB*	*IC*
Thickness of the design ridge consolidated layer (*m*)	1.5	1.5	1.2	1.0
Total thickness of the design ridge H_r (*m*)	8	8	6.5	5
Initial ridge penetration speed (longitudinal loads) (*m/s*)	4	2	2	2
Initial ridge penetration speed (transversal loads) (*m/s*)	2	1	1	1

Table I8.31 Parameters for calculating maximum loads when the thruster penetrates an ice ridge (Thruster first mode such as double acting ships)

	IA Super	*IA*	*IB*	*IC*
Thickness of the design ridge consolidated layer (*m*)	1.5	1.5	1.2	1.0
Total thickness of the design ridge H_r (*m*)	8	8	6.5	5
Initial ridge penetration speed (longitudinal loads) (*m/s*)	6	4	4	4
Initial ridge penetration speed (transversal loads) (*m/s*)	3	2	2	2

(4) The stresses on the thruster are to be calculated for the extreme once-in-a-lifetime loads described in this **8.6.5**. The nominal von Mises stresses on the thruster body are to have a safety margin of 1.3 against the yielding strength of the material. At areas of local stress concentrations, stresses are to have a safety margin of 1.0 against yielding. The slewing bearing, bolt connections and other components are to be able to maintain operability without incurring damage that requires repair when subject to the loads given in **(2)** and **(3)** multiplied by a safety factor of 1.3.

(5) The global vibratory behavior of the thruster body is to be evaluated, when considering cases where first blade order excitations are in the same frequency range with the thruster global modes of vibration, which occur when the propeller rotational speeds are in the high power range of the propulsion line. Based upon this evaluation, the following **(a)** or **(b)** is to be shown. When estimating thruster global natural frequencies in the longitudinal and transverse direction, the damping and added mass due to water are to be taken into account. In addition to this, the effect of ship attachment stiffness is to be modelled.

(a) There is either no global first blade order resonance at high operational propeller speeds (above 50% of maximum power).
(b) The structure is designed to withstand vibratory loads during resonance above 50% of maximum power.

~~**8.6.6 Vibrations**~~

~~The propulsion system shall be designed in such a way that the complete dynamic system is free from dominant torsional, axial, and bending resonances within the designed running speed range, extended by 20% above and below the maximum and minimum operating rotational speeds. If this condition cannot be fulfilled, a detailed vibration analysis has to be carried out in order to determine that the acceptable strength of the components can be achieved.~~

8.9 Miscellaneous Machinery Requirements

Paragraph 8.9.2 has been amended as follows.

8.9.2 Sea Inlet and Cooling Water Systems

1 Cooling water systems are to be designed to ~~ensure a~~ secure the supply of cooling water when navigating in ice.
(-2 to -4 are omitted.)
5 Arrangements for using ballast water for cooling purposes may be useful as a reserve in terms of ~~the~~ ballast ~~condition~~, but cannot be accepted as a substitute for the ~~sea~~ inlet chests described above.

EFFECTIVE DATE AND APPLICATION (Amendment 1-2)

1. The effective date of the amendments is 1 January 2019.
2. Notwithstanding the amendments to the Rules, the current requirements apply to ships for which the date of contract for construction is before the effective date.
3. Notwithstanding the provision of preceding **2.**, the amendments to the Rules may apply to ships for which the date of contract for construction is on or after 1 December 2017 upon request of the owner.

Amendment 1-3

Chapter 1 GENERAL

1.1 General

1.1.2 Documentation*

Sub-paragraph -3 has been amended as follows.

3 For ice class ships, the upper ice water line specified in **1.2.1(23)**, the lower ice waterline specified in **1.2.1(24)** ~~and~~, hull area specified in **1.2.2(2)**, ~~are to be indicated in the shell expansion specified in **2.1.2, Part B**. T~~the engine output defined in **8.4.2**, the displacement defined in **8.1.2-6** and the dimensions necessary for the engine output calculation required in **8.4.2** are to be indicated in the ~~general arrangement~~ shell expansion specified in **2.1.2, Part B**.

1.2 Definitions

1.2.1 Terms*

Sub-paragraph (2) has been amended as follows.

The definitions of terms which appear in this Part are to be as specified in the following **(1)** to **(27)**, unless specified elsewhere.

(1) "Category *A* ship" is a ship designed for operation in polar waters in at least medium first-year ice, which may include old ice inclusions.

(2) "Category *B* ship" is a ship not included in category *A*, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions.

(3) "Category *C* ship" is a ship designed to operate in open water or in ice conditions less severe than those included in categories *A* and *B*.

Chapter 8 ICE CLASS SHIPS

8.3 Hull Structures and Equipment

8.3.1 Shell Plating

Sub-paragraphs -1 and -2 have been amended as follows.

1 The vertical extension of the ice belt is to be as given in **Table I8.6** according to the ice class and is to comply with the following requirements.

(1) Fore foot

For I*A Super* ice class ships with the shell plating below the ice belt from the stem to a position five main frame spaces abaft the point where the bow profile departs from the keel line is to ~~have at least the thickness required in the ice belt in the midbody region~~ be ice-strengthened in the same way as the bow region.

(2) Upper bow ice belt

For I*A Super* and I*A* ice class ships with an open water service speed equal to or exceeding 18 *knots*, the shell plate from the upper limit of the ice belt to 2*m* above it and from the stem to a position at least 0.2*L* abaft the forward perpendicular, is to ~~have at least the thickness required in the ice belt in~~ be ice-strengthened in the same way as the midbody region. A similar strengthening of the bow region is to apply to a ship with lower service speed, when it is, *e.g.* on the basis of the model tests, evident that the ship will have a high bow wave.

(3) Side scuttles are not to be situated in the ice belt.

(4) If the weather deck in any part of the ship is situated below the upper limit of the ice belt, the bulwark and the construction of the freeing ports are to be given at least the same strength as is required for the shell in the ice belt.

2 The thickness of shell plating in the ice belt is not to be less than that obtained from the following formula according to the type of framing.

For the transverse framing: $667s\sqrt{\dfrac{f_1 p_{PL}}{\sigma_y}} + t_c \quad (mm)$

For the longitudinal framing: $667s\sqrt{\dfrac{p}{f_2 \sigma_y}} + t_C \quad (mm)$

where

s : Frame spacing (m)

p_{PL} : $0.75p$ (MPa)

p : As specified in **8.2.1-1**

f_1 : As given in the following formula. Where, however, f_1 is greater than 1.0, f_1 is to be taken as 1.0.

$$1.3 - \frac{4.2}{(h/s+1.8)^2}$$

f_2 : As given in the following formula depending on the value of h/s

where $h/s < 1.0$: $0.6 + \dfrac{0.4}{h/s}$

where $1.0 \le h/s < 1.8$: $1.4 - 0.4\ (h/s)$

h : As specified in **8.2.1-2**

σ_y : Yield stress of the materials (N/mm^2),
for which the following values are to be used
235 N/mm^2 for normal-strength hull structural steel
315 N/mm^2 for high-strength hull structural steel
However, if steels with different yield stresses than those given above are used, the value is to be at the discretion of the Society.

t_c : 2mm: If special surface coating, by experience shown capable to withstand the abrasion ~~of~~ by ice, is applied and maintained, lower values may be approved.

8.3.2 General Requirements for Frames*

Sub-paragraphs -1 and -3 have been amended as follows.

1 The vertical extension of the ice strengthening of the framing is to be at least as given in **Table I8.7** according to the respective ice classes and regions. Where an upper bow ice belt is required in **8.3.1-1**, the ice strengthening part of the framing is to be extended at least to the top of this ice belt. Where the ice strengthening would go beyond a deck, the top or bottom plating of a tank or tank top by no more than 250mm, it can be terminated at that deck, top or bottom plating of the tank or tank top.

3 ~~In all regions for I*A Super* ice class ships, in the bow and midbody regions for I*A* ice class ships and in the bow regions for I*B*, I*C* and I*D* ice class ships, t~~The following are to apply ~~in the ice strengthening area~~ to support of frames against instability, in particular tripping:

(1) The frames are to be attached to the shell by double continuous welds. No scalloping is allowed except when crossing shell plate butts.

(2) The web thickness of the frames is not to be less than the greatest of the following **(a)** to **(~~d~~c)**.

(a) $\dfrac{h_w\sqrt{\sigma_y}}{C}$

h_w: web height (mm)
C: 805 for profiles
282 for flat bars
σ_y : As specified in **8.3.1-2**

~~(b) 2.5% of the frame spacing for transverse frames~~

(~~c~~b) Half of the net thickness of the shell plating $t-t_c$. For the purpose of calculating the minimum web thickness of frames, the required thickness of the shell plating is to be calculated according to **8.3.1-2** using the yield strength σ_y of the frames

(~~d~~c) 9 mm

(3) Where there is a deck, top or bottom plating of a tank, tank top or bulkhead in lieu of a frame, the plate thickness of this is to be as per the preceding **(2)**, to a depth corresponding to the height of adjacent frames. In such a case, the material properties of the deck, top or bottom plating of the tank, tank top or bulkhead and the frame height h_w of the adjacent frames are to be used in the calculations, and the constant C is to be 805.

(4) ~~Frames that are not normal to the plating or the profile is unsymmetrical, and the span exceeds 4.0 *m*, are to be supported against tripping by brackets, intercostals, stringers or similar at a distance not exceeding 1.3 *m*. If the span is less than 4.0 *m*, the supports against tripping are required for unsymmetrical profiles and stiffeners for webs which are not normal to plating.~~ Asymmetrical frames and frames which are not at right angles to the shell (web

less than 90 degrees to the shell) are to be supported against tripping by brackets, intercoastals, stringers or similar, at a distance not exceeding 1,300 *mm*. For frames with spans greater than 4 *m*, the extent of antitripping supports is to be applied to all regions and for all ice classes. For frames with spans less than or equal to 4 *m*, the extent of antitripping supports is to be applied to all regions for ice class I*A Super*, to the bow and midbody regions for ice class I*A*, and to the bow region for ice classes I*B* and I*C*. Direct calculation methods may be applied to demonstrate the equivalent level of support provided by alternative arrangements.

Table I8.7 has been amended as follows.

Table I8.7 Vertical Extension of the Ice Strengthening of Framing

Ice Class	Hull region	Above the *UIWL*	Below the *LIWL*
I*A Super*	Bow	1.2 *m*	Down to ~~double bottom~~ tank top or below top of the floors
	Midbody		2.0*m*
	Stern		1.6*m*
I*A* I*B* I*C*	Bow	1.0 *m*	1.6*m*
	Midbody		1.3*m*
	Stern		1.0*m*
I*D*	Bow	1.0 *m*	1.6*m*

8.3.3 Transverse Frames

Sub-paragraphs -3 and -4 have been amended as follows.

3 The upper end of the strengthening part of a main frame and of an intermediate frame are to be attached to a deck, top or bottom plating of a tank or an ice stringer as specified in **8.3.5**. Where a frame terminates above a deck or a stringer (hereinafter, referred to as the lower deck in this section) which is situated at or above the upper limit of the ice belt, the part of the frame above the lower deck is to be in accordance with the followings:

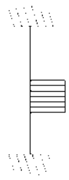
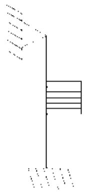
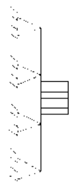
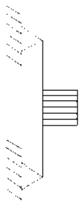
(1) the part of the main frame and the intermediate frame may have the scantlings required by the ordinary frame; and

(2) the upper end of the main frame and the intermediate frame is to be connected to a deck which situated above the lower deck (hereinafter, referred to as the higher deck in this section). However, the upper end of the intermediate frame may be connected to the adjacent main frames by a horizontal stiffener having the same scantlings as the main frame.

4 The lower end of the strengthened part of a main frame and of an intermediate ice frame is to be attached to a deck, top or bottom plating of a tank, tank top or ice stringer specified in **8.3.5**. Where an intermediate frame terminates below a deck, top or bottom plating of a tank, tank top or ice stringer which is situated at or below the lower limit of the ice belt, the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the frames.

Table I8.8 has been amended as follows.

Table I8.8 Value of m_0

Boundary condition	m_0	Example
	7.0	Frames in a bulk carrier with top side tanks
	6.0	Frames extending from the tank top to the upper deck of a single decked ship
	5.7	Continuous frames between several decks or stringers
	5.0	Frames extending between two decks only

Note:
The boundary conditions are those for the main and intermediate frames. Load is applied at mid span.

8.3.4 Longitudinal Frames*

Sub-paragraph -1 has been amended as follows.

1 The section modulus and effective shear area of a longitudinal frame in the extension specified in **8.3.2-1** are not to be less than those obtained by the following formulae. However, in calculating the actual shear area of the frames, the area of the brackets is not to be taken into account:

Section modulus : $\dfrac{f_4 phl^2}{m\sigma_y}\times 10^6 \quad (cm^3)$

Effective shear area : $\dfrac{\sqrt{3} f_4 f_5 phl}{2\sigma_y}\times 10^4 \quad (cm^2)$

f_4 : Factor which takes account of the load distribution to adjacent frames as given by the following formula.
$(1-0.2h/s)$

f_5: Factor which takes into account the pressure definition and maximum shear force versus load location and also the shear stress distribution, taken as 2.16

h : As specified in **8.2.1-2**
s : Frame spacing (m) (See the note to **Table I8.4**)
p : As specified in **8.2.1-1**
l : Span of the longitudinal frame (m) (See the note to **Table I8.4**)
m : Boundary condition factor is to be taken as 13.3 for a continuous beam with brackets. Where the boundary conditions deviate significantly from those of a continuous beam with brackets, a smaller boundary factor is to be adapted. ~~For frames without brackets, the boundary condition factor is to be taken as 11.0.~~
σ_y : As specified in **8.3.1-2**

8.3.5 Ice Stringers*

Sub-paragraph -3 has been amended as follows.

3 Narrow deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area requirements in the preceding **-1** and **-2** respectively. In the case of very long hatches, the product p and h may be taken as less than 0.15 but in no case less than 0.10. Regard is to be paid to the deflection of the ship's sides due to ice pressure ~~in way of~~ with respect to very long hatch openings, when designing weather deck, hatch covers and their fittings.

8.3.9 Stern*

Sub-paragraphs -2 and -4 have been amended as follows.

2 On twin and triple screw ships, the ice strengthening of the shell and framing are to be extended to the ~~double bottom~~ tank top for 1.5 *metres* forward and aft of the side propellers.
4 The introduction of new propulsion arrangements with azimuthing thrusters ~~or podded propellers~~, which provide an improved maneuverability, will result in increased ice loading of the stern region and the stern area. This fact is to be considered in the design of the aft/stern structure.

EFFECTIVE DATE AND APPLICATION (Amendment 1-3)

1. The effective date of the amendments is 1 January 2019.
2. Notwithstanding the amendments to the Rules, the current requirements apply to ships for which the date of contract for construction is before the effective date.

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part I

Ships Operating in Polar Waters, Polar Class Ships and Ice Class Ships

GUIDANCE

2018 AMENDMENT NO.1

Notice No.103 25 December 2018

Resolved by Technical Committee on 1 August 2018

Notice No.103 25 December 2018
AMENDMENT TO THE GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Guidance for the survey and construction of steel ships" has been partly amended as follows:

Part I SHIPS OPERATING IN POLAR WATERS, POLAR CLASS SHIPS AND ICE CLASS SHIPS

Amendment 1-1

I1 GENERAL APPLICATION

I1.2 Definitions

I1.2.2 Ice Class Ships

Sub-paragraph -2 has been amended as follows.

2 The correspondence of ice classes specified in **1.2.2, Part I of the Rules** with those in the *Arctic Shipping Safety and Pollution Prevention Regulations* is as given in **Table I1.2.2-2**.

Table I1.2.2-2 has been amended as follows.

Table I1.2.2-2 The Correspondence of Ice Classes between the Rules and the *Arctic Shipping Safety and Pollution Prevention Regulations*

Ice Class of the *Arctic shipping Safety and Pollution Prevention Regulations*	Ice Class of the Rules
Type A	I*A Super*
Type B	I*A*
Type C	I*B*
Type D	I*C* ~~I*D*~~
Type E	No ice class I*D*

EFFECTIVE DATE AND APPLICATION (Amendment 1-1)

1. The effective date of the amendments is 25 December 2018.

Amendment 1-2

I1 GENERAL APPLICATION

I1.1 General

Paragraph I1.2.2 has been amended as follows.

I1.2.2 Ice Class Ships

1 The correspondence of ice classes specified in **1.2.2, Part I of the Rules** with those in the _2017_ *Finnish-Swedish Ice Class Rules* ~~2010~~ is as given in **Table I1.2.2-1**.
(-2 and -3 are omitted.)

Table I1.2.2-1 The Correspondence of Ice Classes between the Rules and the _2017_ *Finnish-Swedish Ice Class Rules* ~~2010~~

Ice Class of the _2017_ *Finnish-Swedish Ice Class Rules* ~~2010~~	Ice Class of the Rules
I*A Super*	I*A Super*
I*A*	I*A*
I*B*	I*B*
I*C*	I*C*
II	I*D* No ice class

I8 ICE CLASS SHIPS

I8.7 Alternative Designs

I8.7.1 Alternative Design

Sub-paragraph (3) has been amended as follows.

The examination specified in **8.7, Part I of the Rules**, may be according to the following **(1)** to **(3)**.

((1) and (2) are omitted.)

(3) Design levels

(a) Analysis is to ~~indicate~~ confirm that all components transmitting random (occasional) forces, excluding propeller blade, are not subjected to stress levels in excess of the yield stress of the component material, within a reasonable safety margin.

(b) Cumulative fatigue damage calculations are to ~~indicate~~ give reasonable safety factors. Due account is to be taken of material properties, stress raisers, and fatigue enhancements.

(c) Vibration analysis is to be ~~carried out~~ performed and ~~is to indicate~~ demonstrate that ~~complete~~ overall dynamic systems are free ~~from~~ of the harmful torsional resonances resulting from propeller/ice interaction.

EFFECTIVE DATE AND APPLICATION (Amendment 1-2)

1. The effective date of the amendments is 1 January 2019.

2. Notwithstanding the amendments to the Guidance, the current requirements apply to ships for which the date of contract for construction is before the effective date.

3. Notwithstanding the provision of preceding **2.**, the amendments to the Guidance may apply to ships for which the date of contract for construction is on or after 1 December 2017 upon request of the owner.

Amendment 1-3

I8 ICE CLASS SHIPS

I8.1 General

I8.1.1 Application

Sub-paragraph -1 has been amended as follows.

1 For ice class ships trading in the Northern Baltic in the winter under the control of the regulation "*2017 Finnish-Swedish Ice Class Rules ~~2010~~*", regard needs to be paid to the following as extracted from "*Guidelines for the Application of the Finnish-Swedish Ice Class Rules*".

(1) The Finland and Swedish administrations ~~of Sweden and Finland~~ provide icebreaker assistance to ~~ice class~~ ships bound for ports in ~~respective~~ these two countries ~~in~~ during the winter season. Depending on the ice conditions, restrictions ~~in~~ are enforced with regard to the size and ice class of ships entitled to icebreaker assistance ~~are enforced~~.

(2) It should not be assumed that mere ~~Merely the~~ compliance with these regulations ~~must not be assumed to~~ guarantees ~~any~~ a certain degree of capability to advance in ice without icebreaker assistance, or ~~nor~~ to withstand heavy ice ~~jamming~~ compression in the open sea, where the ice field may move due to high wind speeds.

(3) It should be noted that the ice-going capacity of small ~~ice class~~ ships ~~will have~~ may be somewhat ~~less ice-going capability as compared with~~ lower than that of larger ~~ice class~~ ships ~~having~~ in the same ice class.

(4) ~~It shall be noted that for ice class ships of moderate size (displacement not exceeding 30,000 *tons*) n~~Notch towing ~~in many situations~~ is often the most efficient way of assisting ~~in ice~~ ships of moderate size (with a displacement not exceeding 30,000 *tons*).

(5) Ice class ships with a bulb protruding more than 2.5*m* forward of the forward perpendicular, ice class ships with too blunt of a bow shape and ice class ships with an ice knife fitted above the bulb are often difficult for notch towing.

(6) ~~When~~ If the bow is too high in ~~the~~ ballast condition, ~~ice class~~ the ship~~s may~~ could be trimmed to ~~get~~ lower the bow ~~down~~.

(7) An ice strengthened ship is assumed to operate in open sea conditions corresponding to a level ice thickness not exceeding h_0. The design ice load height (h) of the area actually under ice pressure at any particular point of time is, however, assumed to be only a fraction of the ice thickness. The values for h_0 and h are given in **Table I8.1.1-1**.

I8.3 Hull Structures and Equipments

Paragraph I8.3.6 has been added as follows.

I8.3.6 Web Frames

With respect to the provisions of **8.3.6-4**, when the direct analysis is not based on beam theory, the allowable shear stress is to be τ_y.

EFFECTIVE DATE AND APPLICATION (Amendment 1-3)

1. The effective date of the amendments is 1 January 2019.

2. Notwithstanding the amendments to the Guidance, the current requirements apply to ships for which the date of contract for construction is before the effective date.