Propellers and Azimuth Thrusters of Ice Class Ships

Amended Rules and Guidance

Rules for the Survey and Construction of Steel Ships Part I
Guidance for the Survey and Construction of Steel Ships Part I

Reason for Amendment

Requirements for the ice strengthening of ships which are intended to navigate in the Northern Baltic (Ice Class Ships) complying with the Finnish-Swedish Ice Class Rules (FSICR) are specified in Chapter 8, Part I of Rules for the Survey and Construction of Steel Ships.

In July 2021, amendments to the FSICR were adopted and relevant requirements are accordingly amended based on the most recent version of the FSICR.

Outline of Amendment

The main contents of this amendment are as follows:

(1) Revises the numerical values for parameters in formulae used to determine whether fatigue calculations are necessary for propeller blades of Ice Class Ships.

(2) Clarifies that the parameter "impacting part sphere radius R_c" is to be used in formulae for calculating ice impact loads on azimuth thrusters of Ice Class Ships when contact surfaces are hemispherical in shape.

“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

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* 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*

1 (Omitted)

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 ~~*2017*~~ *Finnish-Swedish Ice Class Rules* or in the Canadian Arctic complying with the *Arctic Shipping Safety and Pollution Prevention Regulations*.

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

8.5.9 Design Torque on Propulsion Shafting System

Sub-paragraph -3 has been amended as follows.

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

(Table is omitted.)

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

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

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

Sub-paragraph -4(3) has been deleted.

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) to (2) are omitted.)

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

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

8.6.2 Propeller Blade Stresses

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 **-4**. The equivalent stress is normalised for 10^8 cycles. For materials with a two-slope S-N curve (See **Fig. I8.11**), the fatigue calculations specified in this section are not required if the following criterion is fulfilled.

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

where

The coefficients B_1, B_2 and B_3 are as given in the **Table I8.22**.

Table I8.22 has been amended as follows.

Table I8.22 The Coefficients B_1, B_2 and B_3

Coefficients	Open propeller	Ducted propeller
B_1	0.00328~~0.00246~~	~~0.00167~~0.00223
B_2	1.0076~~0.947~~	~~0.956~~1.0071
B_3	2.101	~~2.470~~2.471

8.6.5 Azimuthing Main Propulsors*

With respect to the azimuthing main propulsors, the followings are to be complied with in addition to the requirements specified in **8.6.1**:

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

(2) Extreme ice impact loads

(a) (Omitted)

(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.

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

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} instead of R_c is to be used, where R_{ceq} is estimated using the equation below.

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

where

A: The max contact area that the ice block can have. When determining A, the dimensions of the relevant part of the thruster as well as the size of the ice block need to be considered.

If the $2R_{ceq}$ is greater than the ice block thickness, R_{ceq} is set to half of the ice block thickness. This limitation is not valid for the impact on the propeller hub or thruster end cap (load case T1a and T2a). 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 I8.27 and Table I8.28 have been amended as follows.

Table I8.27 Impact speeds for aft centerline thruster

	IA Super	IA	IB	IC
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

	IA Super	IA	IB	IC
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

"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

I1 GENERAL APPLICATION

I1.2 Definitions

I1.2.2 Ice Class Ships

Sub-paragraph -1 has been amended as follows.

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* is as given in **Table I1.2.2-1**.
2 (Omitted)
3 (Omitted)

Table I1.2.2-1 has been amended as follows.

Table I1.2.2-1 The Correspondence of Ice Classes between the Rules and the ~~2017~~ *Finnish-Swedish Ice Class Rules*

Ice Class of the ~~2017~~ *Finnish-Swedish Ice Class Rules*	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

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

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*, regard needs to be paid to the following as extracted from *Guidelines for the Application of the Finnish-Swedish Ice Class Rules*.
((1) to (7) are omitted.)