Tasneef
هيئة الإمارات للتصنيف
Emirates Classification Society

Amendments to the "Rules for the Classification of Ships" - Part F, Chapter 9 - ICE CLASS (ICE)

RFC/002/AMN/07

Effective from 1/4/2021

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SECTION 3 MACHINERY

1 Propulsion

1.1 Propulsion machinery performance

1.1.1 *(1/7/2020)*

The engine output P is the total maximum output that the propulsion machinery can continuously deliver to the propeller. If the output of the machinery is restricted by technical means or by any regulations applicable to the ship, P is to be taken as the restricted output. In no case may P be less than the values calculated in accordance with Sec 1, [3.1.2] or Sec 1, [3.1.4], as applicable. 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.

2 Class notations IAS, IA, IB and IC

2.1 Propulsion machinery

2.1.1 Scope (1/7/2020)

These requirements apply to propulsion machinery covering open- and ducted-type propellers with controllable pitch or fixed pitch design for the ice classes IAS, IA, IB and IC. The given loads are the expected ice loads throughout the ship's service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. The regulations also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller-ice interaction; the given azimuthing thruster body loads are the expected ice loads for the ship's service life under normal operational conditions. The local strength of the thruster body is to be sufficient to withstand local ice pressure when the thruster body is designed for extreme loads. However, the load models of the regulations do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially) or the load case when an ice block hits the propeller hub of a pulling propeller. Ice loads resulting from ice impacts on the body of thrusters are to be estimated, but ice load formulae are not available.

The thruster global vibrations caused by blade order excitation on the propeller may cause significant vibratory loads.

2.2 Symbols

2.2.1 (1/7/2020)

The symbols used in the formulae of this Section have the meaning indicated hereinafter. The loads considered are defined in Tab 1.

c : chord length of blade section, in m;

$c_{0,7}$: chord length of blade section at 0,7R propeller radius, in m

CP : controllable pitch

D : propeller diameter, in m

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

D_{limit} : limit value for propeller diameter, in m

EAR : expanded blade area ratio;

F_b : maximum backward blade force for the ship's service life, in kN;

F_{ex} : ultimate blade load resulting from blade loss through plastic bending, in kN

F_f : maximum forward blade force for the ship's service life, in kN

F_{ice} : ice load, in kN

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

FP : fixed pitch

h_0 : depth of the propeller centreline from lower ice waterline, in m

h_{ice} : thickness of maximum design ice block entering propeller, in m

I : equivalent mass moment of inertia of all parts on engine side of component under consideration, in kgm^2

I_t : equivalent mass moment of inertia of the whole propulsion system, in kgm^2

k : shape parameter for Weibull distribution

LIWL : lower ice waterline, in m

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

M_{BL} : blade bending moment

MCR : maximum continuous rating

n : propeller rotational speed, in rev./s

n_n : nominal propeller rotational speed at MCR in free running condition, in rev./s

N_{class} : reference number of impacts per propeller rotational speed per ice class

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

N_R : reference number of load for equivalent fatigue stress (10^8 cycles)

N_Q : number of propeller revolutions during a milling sequence

$P_{0,7}$: propeller pitch at 0,7R radius, in m

$P_{0,7n}$: propeller pitch at 0,7R radius at MCR in free running condition, in m

$P_{0,7b}$: propeller pitch at 0,7R radius at MCR in bollard condition, in m

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$\sigma_{0,2}$ minimum yield or 0.2% proof strength to be specified on the drawing

c, t, and r are, respectively, the length, thickness, and radius of the cylindrical root section of the blade at the weakest section outside the root filet.

2.5.6 Spindle Torque, Q_{sex} *(1/7/2020)*

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.

$Q_{sex} = \max(C_{LE0,8};0,8 \cdot C_{TE0,8}) \cdot C_{spex} \cdot F_{ex}$ [kNm]

where

$$C_{spex} = C_{sp} \cdot C_{fex} = 0,7 \cdot \left(1 - \left(\frac{4 \cdot EAR}{Z}\right)^3\right)$$

C_{sp} is a non-dimensional parameter taking account of the spindle arm

C_{fex} is a non-dimensional parameter taking account of the reduction of the blade failure force at the location of the maximum spindle torque.

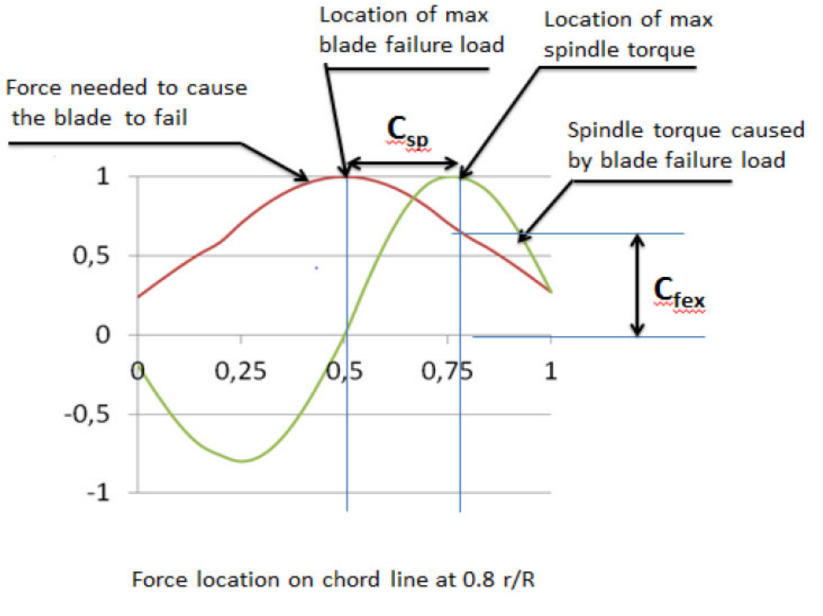
If C_{spex} is below 0,3, a value of 0,3 is to be used for C_{spex}

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

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

Fig 6 illustrates the spindle torque values due to blade failure loads across the entire chord length.

Figure 6 : 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. *(1/7/2020)*



2.6 Design

2.6.1 Design principle

The strength of the propulsion line is to be designed according to the pyramid strength principle.

This means that the loss of the propeller blade is not to cause any significant damage to other propeller shaft line components.

2.6.2 Propeller blade *(1/4/2021)*

a) Calculation of blade stresses

The blade stresses are to be calculated for the design loads given in [2.5.2]. Finite element analysis is to be used for stress analysis for final approval for all propellers. When this analysis is carried out by the Designer, it is to be submitted to the Society. The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area (r/R < 0,5). The root area dimensions based on the following formula can be accepted even if the FEM analysis would show greater stresses at the root area.

$$\sigma_{st} = C_1 \frac{M_{BL}}{100 \cdot ct^2} \text{ [MPa]}$$

where

constant C_1 is the $\dfrac{\text{acutal stress}}{\text{stress obtained with beam equation}}$

If the actual value is not available, C_1 is to be taken as 1,6.

$M_{BL} = (0,75 - r/R) \cdot R \cdot F$, for relative radius r/R < 0,5

F is the maximum of F_b and F_f, whichever is greater.

b) Acceptability criterion

The following criterion for calculated blade stresses is to be fulfilled.

$(\sigma_{ref2} / \sigma_{st}) \geq 1,5$

where:

σ_{st} is the calculated stress for the design loads. If FEM analysis is used in estimating the stresses, von Mises stresses are to be used.

σ_{ref2} is the reference stress, defined as:

$\sigma_{ref2} = 0,7 \cdot \sigma_u$ or

$\sigma_{ref2} = 0,6 \cdot \sigma_{0,2} + 0,4 \cdot \sigma_u$, whichever is the lesser.

c) Fatigue design of propeller blade

The fatigue design of the propeller blade is based on an 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. The equivalent stress is normalised for 100 million cycles.

For material with a two-slope F-N curve if the following criterion is fulfilled, fatigue calculations according to this chapter are not required.

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

where B_1, B_2 and B_3 coefficients for open and ducted propellers are given in Tab 15.

An alternative approach may be accepted by the Society on a case-by-case basis, if deemed equivalent based on the information provided by the manufacturer.

Table 15 *(1/4/2021)*

	Open propeller	Ducted propeller
B_1	0,00~~246~~328	0,00~~167~~223
B_2	~~0,947~~ 1,0076	~~0,956~~ 1,0071
B_3	2,101	2,47~~0~~1

For calculation of equivalent stress, two types of S-N curves are available.

1) Two-slope S-N curve (slopes 4.5 and 10) (see Fig 7).

2) One-slope S-N curve(the slope can be chosen) (see Fig 8).

The type of the S-N curve is to be selected to correspond to the material properties of the blade. If the S-N curve is not known, the two-slope S-N curve is to be used.

Figure 7 : Two-slope S-N curve

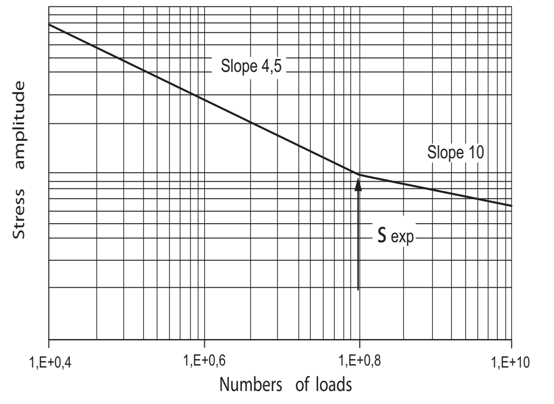
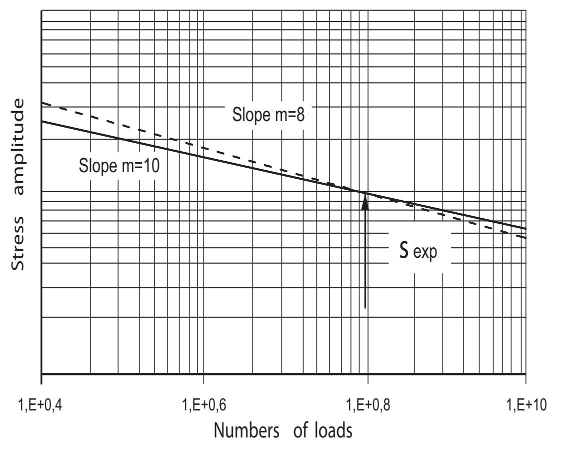


Figure 8 : Constant-slope S-N curve



d) Equivalent fatigue stress:

the equivalent fatigue stress for 100 million stress cycles which produces the same fatigue damage as the load distribution is:

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

where:

$(\sigma_{ice})_{max} = 0,5 \, ((\sigma_{ice})_{f\,max} - (\sigma_{ice})_{b\,max})$

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

$(\sigma_{ice})_{f\,max}$ is the principal stress resulting from forward load

$(\sigma_{ice})_{b\,max}$ is the principal stress resulting from backward load.

In calculation of $(\sigma_{ice})_{max}$, case 1 and case 3 (or case 2 and case 4) are considered as a pair for $(\sigma_{ice})_{f\,max}$, and $(\sigma_{ice})_{b\,max}$ calculations. Case 5 is excluded from the fatigue analysis.

e) Calculation of ρ parameter for two-slope S-N curve:

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formulae.

$\rho = C_1 \cdot (\sigma_{ice})_{max}^{\ C_2} \cdot \sigma_{fl}^{\ C_3} \cdot \log(N_{ice})^{C_4}$

where:

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

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

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